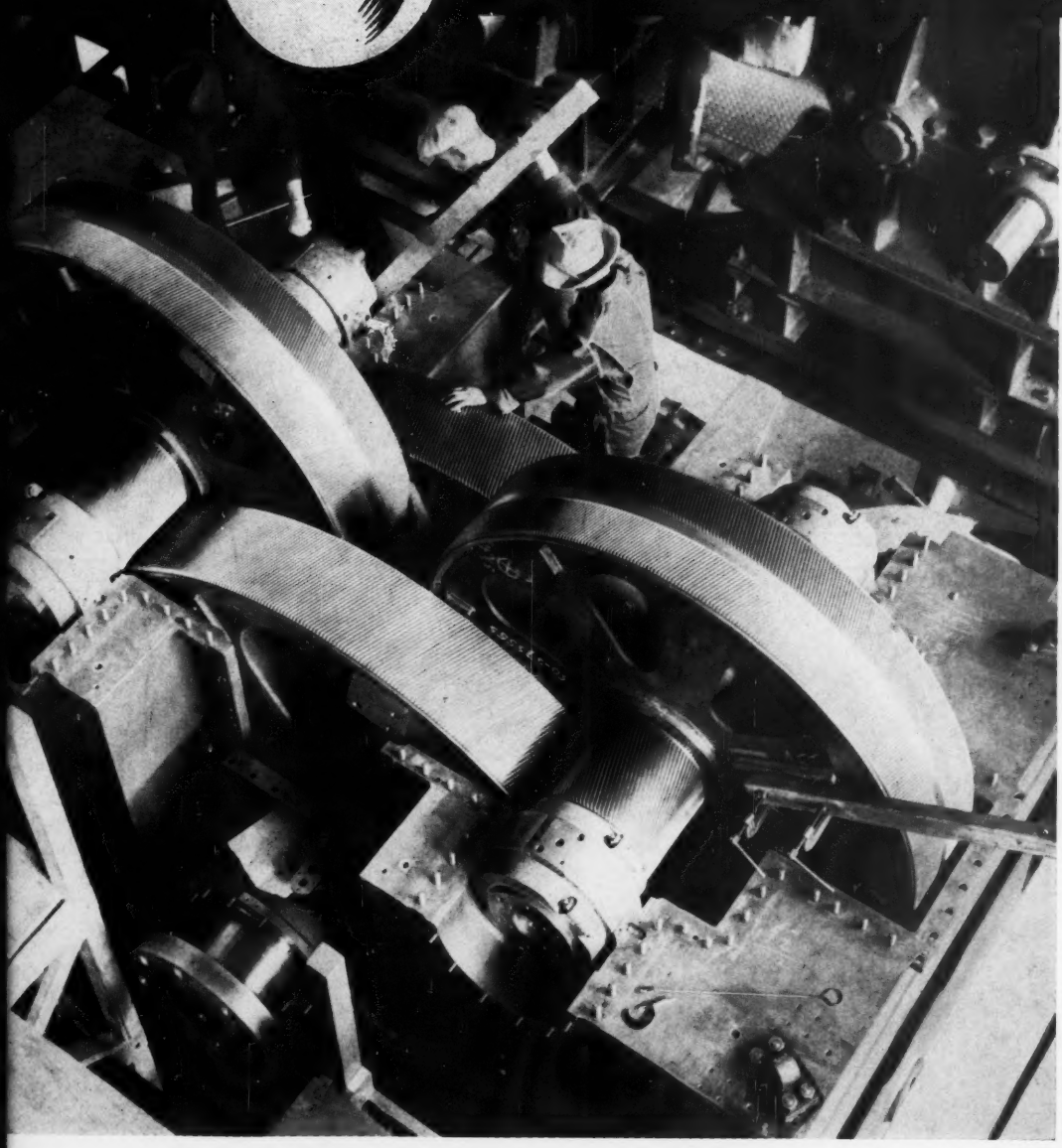
Lubrication ENGINEERING



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Typical Large Marine Reduction Gear Unit—(See Page 85)

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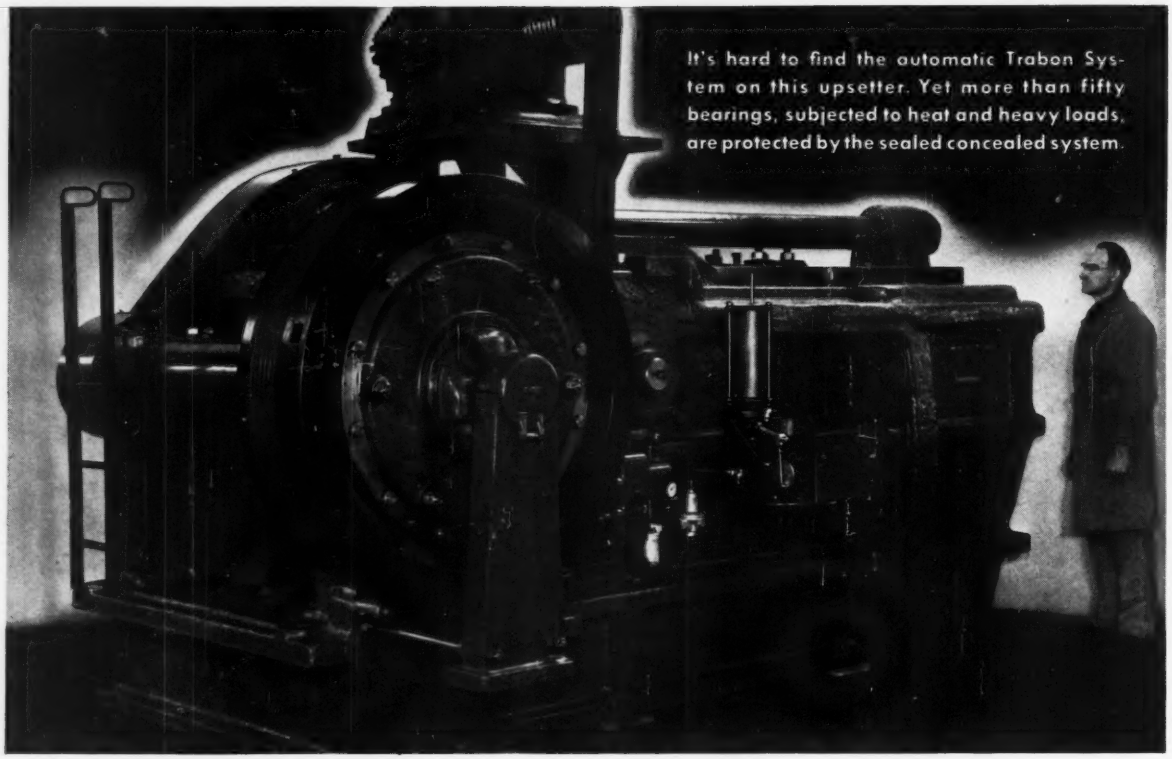
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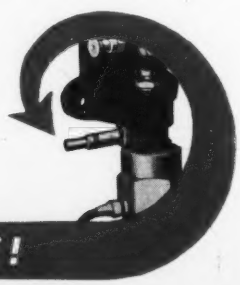

A SINGLE INDICATOR TELLS THE STORY!

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FARVAL—*Studies in Centralized Lubrication* No. 79

Case No. 79—Small Dieing Machines—Chicago

	Hand-Oiled Machines	Farval-equipped Machines
1. Number of Machines	12	5
2. Type of operation	Continuous, 24 hrs. daily*	Continuous, 24 hrs. daily
3. Lubrication Shutdowns	Every 4 hours*	None
4. Bearing history	Frequent failure* Replacements necessary*	Condition excellent No visible wear
5. Maintenance cost	100%	25%
6. Production output	88%	100%

* Continuous operation could not be maintained because of lubrication shutdowns and bearing failures.

FARVAL
CENTRALIZED SYSTEMS OF LUBRICATION

Editorial

THE degree of success attained by any Society in fulfilling its aims and dedicated purposes has been shown to be largely dependent on the cooperation and enthusiasm expressed by its members, its working committees and officers, both national and local. Although still very young, our Society enjoys full measure of these qualities and has a growing committee activity which will be helpful in enabling the Society to contribute materially to the many aspects of lubrication research, application, manufacture and education.

In order to function most effectively the committee programs should be supplemented with comments, criticism and suggestions from the membership, for no matter how competent a committee may be, the collective intellect and imagination of the membership can contribute much toward its guidance. I am sure that all of the committees of our Society are eager to have the benefit of the thoughts and talents of the membership and invite and will welcome its assistance.

One of the major tasks of the Program, Planning and Publications Committee at this time is the preparation for our annual spring Convention to be held in Pittsburgh in March. The Committee is endeavoring to select an agenda which they hope will surpass our first fine Convention which was whole-heartedly received. As before, the focus of the meetings will be outstanding technical papers relating to the many fields of lubrication engineering. These articles will be augmented with prepared and spontaneous discussion. Your suggestions in connection with the Convention program will be indeed helpful and will be gratefully received by the members of the Committee. Suggestions regarding possible subjects or material for original technical papers and speakers of extraordinary ability are invited.

Dr. Kipp, President of our Society, has aptly pointed out the importance of our JOURNAL as a medium for assembling, correlating and weighing the knowledge, ideas, experiences and suggestions of the membership. The Program Planning, and Publications Committee serves in an advisory capacity to our JOURNAL editor and both the Committee members and editor will welcome assistance. Objective study of both Committee activities and JOURNAL contents will aid in enabling the Society to make the utmost in contribution to industry, education and the profession.

We are confident that our Society through its membership, committees and publications will continue to serve in increasing measure to enrich our individual store houses of knowledge, to support allied sciences and engineering, and to broaden the common ground on which our profession meets.

NORMAN C. PENFOLD.

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THE MULTI-PURPOSE CUTTING FLUID

The Development of Lubricating Systems As Applied To Engines*

By CHARLES A. WINSLOW

President, Winslow Engineering Co., Oakland, California

Introduction

IN this paper it is the endeavor of the writer to present a brief outline of the principles involved in lubrication. Methods of applying lubricants to bearings and working surfaces are discussed. Complications arising from the use of various types of lubricants and ways and means of preventing grit from being carried to the bearings with the lubricants are illustrated. Finally, a comparison of results of practical operation of various types of engines in service is made. The data recited is the result of approximately 30 years experience in the designing, patenting, manufacturing and marketing of filters and lubricating systems covered by a long list of patents.[1]

In man's early endeavor to take advantage of one of the greatest inventions in history, the wheel, he begot the problem of stopping the wheel from squeaking and more important, a real problem of prolonging the life of wheels and axle shafts which were obtained by great labor with the primitive methods available. In other words, lubrication was actually a problem in the earliest endeavors of man to improve his living conditions in the evolution of civilization. The first lubricant was probably wet mud and later, most likely animal fat or vegetable oil. The method of application was no doubt very simple.

As man's civilization advanced however, the need for improved transportation methods at higher speeds brought on the problem of better ways and means to lubricate more complicated machinery. In all earlier types of machinery, however, speeds were slow and bearing pressures were relatively light. Some of the most successful early types of machinery were driven with steam power and involved boiler and bearing pressures that today certainly seem very primitive. For example, in some of the early and relatively successful marine steam engines, the paddle wheels operated at approximately 20 to 30 rpm and the pistons, connecting rods, etc., were operated with steam boiler pressures approximating 5 to 10 psi. It can be readily understood that lubricating problems were relatively simple then, as compared to a modern steam engine wherein the turbine is driven at 3000 rpm or better with steam pressures even as high as 1200 psi or greater. Additional problems encountered in gear reduction of the turbine to the propeller involves still further special lubricant applications and types of lubricants for the continuous successful operation of the machinery.

* * * * * *

Many years of experience on many different types and sizes of equipment qualify the author of this paper to discuss the various methods employed to condition lubricating oils in use.

* * * * * *

Development of Bearing Lubrication

As an example of comparison, Figure 1 (front cover) illustrates a modern marine reduction gear drive with gears and bearings machined to fractions of thousandths of an inch. Successful lubrication of this type of machinery requires scientifically compounded lubricants and methods of application. Notwithstanding the relative difference between the earlier and later types of steam engines, internal combustion engines impose still greater demands on lubricating oil and complicate its successful application on bearings and working surfaces. In this case the oil is subjected to extremely high shock loads and temperatures beyond the flash point of the lubricant. In addition to the severe temperature and pressure requirements, the oil must operate with the addition of contaminants which to all intents and purposes change the specification of the oil after five minutes of use to such an extent that it could not be marketed for the lubrication of anything as far as specifications are concerned.

Referring to the methods of application of the lubricant, your attention is directed to Figure 2 illustrating a simple rotating shaft within a housing, forming a bearing which is provided with a simple lubricant duct to convey oil, dirt, or anything that can readily fall into the hole to the bearing.

Figure 3 illustrates a simple bearing operating in a journal box into which grease is forced under pressure. In the early types of slow moving bearings carrying relatively light weight, this was a conventional application of lubricant.

* *Presented at the First Spring Meeting of the American Society of Lubrication Engineers, Chicago, Illinois, April 5 & 6, 1946.*

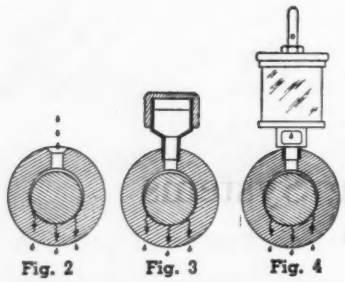

Fig. 2 Fig. 3 Fig. 4

Figure 2. This illustrates a shaft in a bearing housing lubricated with anything that can fall through the oil hole.

Figure 3. A shaft mounted in a housing arranged for lubrication with grease.

Figure 4. A shaft mounted in a housing arranged for lubrication with oil by gravity, etc.

Figure 4 shows a conventional bearing operating in a journal box into which oil is fed either by the capillary action of a wick or by the adjustment of a drip feed. Both methods are still in successful operation on slow speed bearings which do not carry relatively high bearing loads.

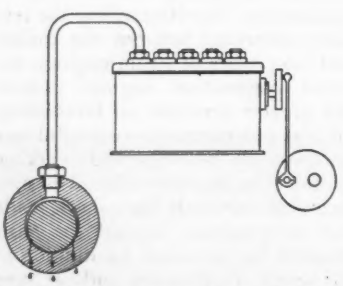

Figure 5. A shaft operating in a journal lubricated with metered oil under pressure.

Figure 5 illustrates the same general type of shaft operating in a journal box into which is forced a lubricant under pressure by a pump. The forcing of lubricant into a bearing was the beginning of modern lubrication. In all of the above methods however, the lubricant was simply conveyed from the lubricant reservoir to the bearings and was lost after flowing through the bearings to the ends of the journal box.

Figure 6 shows a later and further development of the modern pressure lubricating system wherein the lubricant is forced from a reservoir, through the bearings and returned to the reservoir for re-use.

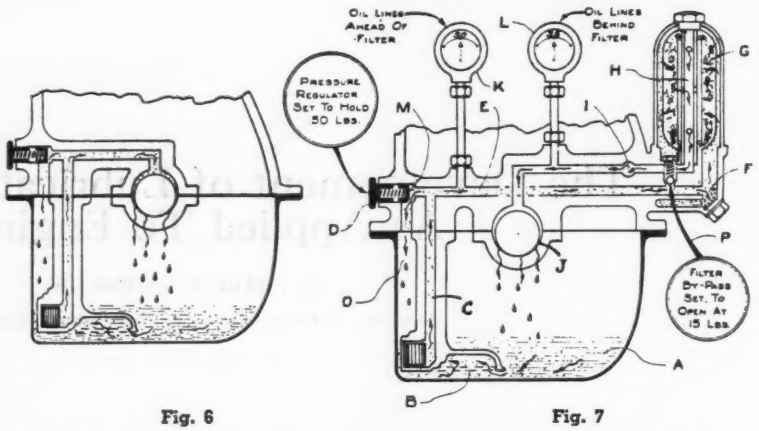

Fig. 6 Fig. 7

Figure 6. Typical pressure system wherein all contaminants including grits, etc., are forced into engine bearings.

Figure 7. Improved pressure system with contamination and grit prevented from entering engine bearings. Operation of same illustrated.

This is the basis of the general types of lubricating systems in common use today and with it comes the complications of preserving the lubricant and circulating it fast enough to take the heat away from the bearings which are now operated at higher speeds and carry extremely great loads by comparison with the earlier machinery developments.

Figure 7 illustrates graphically just how a conventional full pressure lubricating system operates. The system is completely enclosed within the engine casing. Oil is drawn from the bottom of the reservoir or sump (A), through coarse screen (B), to prevent the entry of any particles that would damage the pump gears. In other words, anything that can fit through the coarse screen over the pump suction is picked up and forced along through ducts (C) and (E) with the lubricant to the sump of the fullflow oil filter (F) and trapped out of circulation. The oil flows upward through a filter element (G), where all filterable grit, gums, varnish, etc., are removed. It then passes down through the central outlet duct (H), into the oil header (I) as clean lubricant. It is then forced over into the bearing (J) and returned by leakage back to the crankcase sump at (A).

Gauges (K) and (L) operate to indicate the pressures on the entry duct (E) to the filter and the discharge duct (I) from the filter. The purpose of this illustration is primarily to show what happens to normal gauge pressure with the resistance of a filter built into the oiling system. As the lubricant is forced through the duct (C) to the pressure regulator (D) it meets certain resistance caused by the filter, oil ducts and the bearings. This back pressure as set up in the system causes piston (M) to open, thus discharging a portion of the lubricant back to the crankcase as shown at (O). The adjusting nut (D) can be set to hold any normal gauge pressure on the oiling system. For instance if adjusted to hold 50 lb on duct (E), a certain amount of oil would be forced through duct (E) and the filter to the bearings (J), and the rest of the pumped oil would be by-passed to the crankcase at (O), thus maintaining a 50 lb normal inlet pressure against the lubricating system.

The filter is provided with a by-pass valve (P) which is set to open at approximately 15 lb, initial opening pressure. Assuming that the engine is new and the filter is clean, the oil simply flows through duct (E) into the filter and out of the filter with practically no resistance, therefore, the gauges (K) and (L) would register practically the same pressure in pounds per square inch. As the engine is used and the filter becomes dirty, however, resistance is built up on the outside of the filter element which continues to increase until a pre-determined limit is reached thus permitting oil to flow from duct (E) to (I) without passing through the filter. In this case, assuming that the valve (P) requires 15 lb to open, a balance is set up between the pressure regulator piston (M) and the by-pass

ball check at (P). The piston (M) is set to hold a maximum of 50 lb of oil pressure and spill the rest back to the crankcase. Therefore, the maximum limit is set by the adjusting screw (D). The minimum limit on the bearings is determined by the spring setting on the by-pass ball (P) which in this case, may be 15 lbs. Therefore, if it takes 15 lb to open the valve (P), the pressure reading in the duct (I) will be 50 less 15 which will be shown as 35 psi on the gauge (L).

Any predetermined pressure necessary to force oil through a filter, can be used on the by-pass (P). The higher the by-pass pressure, the longer the filter will operate with completely filtered oil. A high filtering pressure however, forces soot and fine dirt through the filter and causes pressure loss on the bearings. Therefore, from a design standpoint, the question in this case is how far we can safely permit the gauge pressure to drop before opening the by-pass around the filter elements.

To avoid confusion, it should be mentioned that in most systems the operator does not know anything about the pressure in the duct (E), because the conventional gauge registers pressure only on the duct (I). This is the final pressure before oil reaches the bearings and as far as the operator is concerned is all that he needs to know. The initial pressure in the duct from the pump to the filter is of no concern for normal operational purposes. It should be pointed out, however, that in certain designs of pump and filter applications with long small ducts and large lubricant pumps, the writer has witnessed pressures registered higher than 600 psi on filter shells and has seen pressures as high as 1200 psi or more immediately above the pump gears. From this experience, I have always advocated over-size oil passages and pressure regulators relatively close to the lubricant pump to prevent rupture of oil lines, filter casings, gauges, etc., when engines are started up suddenly with cold heavy oil in the crankcase.

At Figure 8, there is illustrated a section of a large engine and a schematic lubricating system in which the lubricant is forced through the bearings under pressure with the splash from the bearings being used to lubricate the working surfaces of the pistons and cylinder walls, cam shaft rotating surfaces, valve tappet extensions, etc. It should be noted a modification of a conventional lubricating system has been illustrated wherein the lubricant is not only forced from the sump or reservoir to the bearings under pressure, but also additional lubricant is forced through the top of the connecting rod onto the bottoms of the pistons. The oil thus thrown on the piston aids the jacket water in removing the heat from the internal hot parts of the engine by conveying same through the medium of the lubricant to a heat exchanger before it is re-cycled back through the pump. In this case the case the lubricant not only lubricates the working surfaces, and is returned for re-circulation, but in each cycle of operation, it is used to convey heat from the operating parts of the engine back to the crankcase and thus serves a dual purpose of removing the heat from the working surfaces as well as lubricating the parts. It can be readily appreciated that this further complicates the lubricating engineer's problem as it involves heat transfer as well as lubrication.

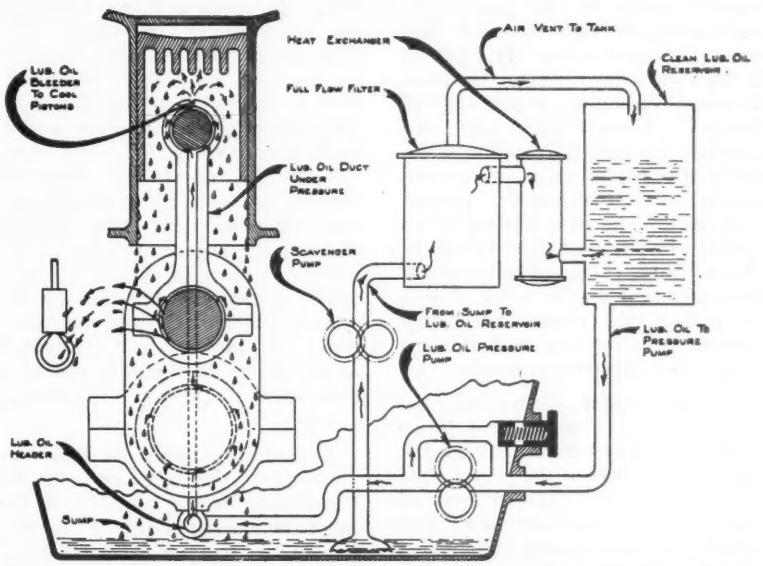

Figure 8. Typical dry sump lubricating system illustrating pressure and splash feed lubrication plus piston cooling with lubricant.

In Figure 9 an improved form of lubricating system is illustrated wherein a conventional lubricant pump forces oil to bearings in the usual manner, but with the addition that the pressure regulator operates in two stages. As the engine is started up with cold oil in the ducts and crankcase, the gear pump forces the heavy oil up through the duct and against the face of the pistons. During operation, oil in the sump (A) is drawn up through the pump

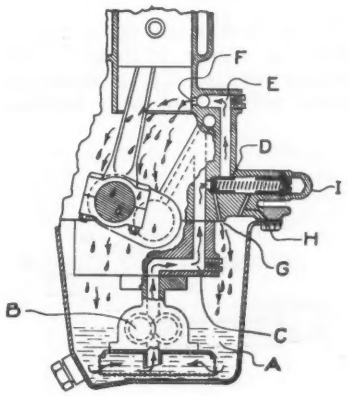

Figure 9. Combination pressure and splash lubricating system. Splash feed is operated by resistance of lubricant through engine bearings when engine is started cold. Pistons and working surfaces are adequately lubricated by splash system which is automatically eliminated when the engine is warm.

suction screen by the pump (B) and forced through the duct (C), against the piston face (D), forcing it back into the pressure regulator housing, causing oil to pass upward through passage (E) and out through the port (F), spilling a copious quantity of oil over the connecting rods, crankshaft, pistons, etc., during the cold starting of an engine. This immediately puts all of the oil in the crankcase into circulation and thus warms it up as well as sealing the pistons and rings against blow-by and fuel dilution from the combustion chamber.

As the engine warms up, the small duct (G) is designed to be large enough to handle all of the by-pass oil and thus as the oil can flow through the duct (G) by reduced viscosity, the secondary lubricating system is immediately eliminated and thus the splash system no longer functions. The duct (H) in the pressure regulator (I) is for the purpose of ventilating the spring compartment in the pressure regulator itself. It should be understood from this description that this system of oiling an engine is actually a dual system. In the first case, we have a primary pressure lubricating system which, during normal operation, functions in a normal manner either with or without a filter. During cold starting periods, however, a secondary splash system is operated by resistance of the primary pressure system and serves to provide a copious supply of lubricants by reasons which are obvious.

A modification of the system is shown in Figure 10 wherein the pressure regulator (J) is shown attached to the base of a full-flow filter (K) which in turn is bolted to the crankcase of an engine (L). This system operates in an identical manner as previously described, that is, the oil entering the duct (M) causes piston (N) to be forced back, into housing (O), thus permitting the oil to be delivered through passage (P) to the pistons, connecting rods and other rotating parts of the engine. As soon as the normal viscosity in the oil is established, it then can flow through the reduced passage (Q) and the splash system is automatically eliminated as the engine continues to run on a conventional pressure lubricating system.

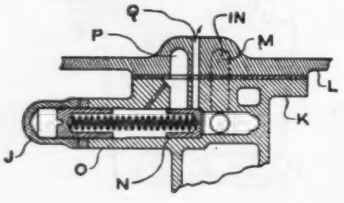

Figure 10. Combination pressure and splash system operated by travel of the piston (N), which opens first the small by-pass (Q) to crankcase and second the large by-pass (P) to splash system. When oil viscosity is reduced by temperature the large by-pass is eliminated, all excess oil going through the small one to the crankcase.

Regarding removal of contaminants from the lubricant and the maintaining of the stability of the lubricant during use, it is a well-known fact that for every pound of fuel used in a conventional gasoline or diesel engine, it is possible to condense approximately 1 lb of water from the exhaust gases. In addition to water formed during operation from the products of combustion, free carbon, gum, varnish, sulphur, metal, grit, and dirt from the intake air, etc., are present in an engine and find their way to the lubricant through various channels. Principal among the evils of ways and means of contaminating lubricating oil is the fact that high combustion pressures are not sealed by pistons, and rings, but gas leaks past pistons, and force particles of unburned fuel, metal, grit and products of combustion into the crankcase where they are mixed with the lubricant by the lubricant pump.

Causes of sludge in engines are too numerous to explain in detail in this paper; therefore, attention is directed to Page 6, Fig. 4 of a recent paper by the writer presented before the Society of Automotive Engineers at Seattle on April 24, 1945, entitled "The How and the Why of Strainers, Screens and Filters as Applied to the Fuel and Lubricating Oil Systems of Engines."

Condition Lubricants During Use

The problems involved in lubricating a steam engine are relatively simple as compared to those involved in lubricating an internal combustion engine. For instance, contamination in a steam plant is generally limited to the wear of metals incorporated in the engines, plus condensation of moisture or water from the steam, etc. These can be readily removed by simple means as is evident by the fact that many steam plants have a simple strainer and centrifuge incorporated in the system for the successful removal of such contaminants from the lubricants. On the other hand, modern internal combustion engines where high combustion pressures are used and relatively high rpm is involved, contamination formed in lubricant is an entirely different matter. As an example, many small compression ignition engines (so-called diesel engines) are known to make as much as 1 lb of sludge per hundred hp-hrs of operation under certain operating conditions. Furthermore, certain types of fuel and elements of mechanical construction and engine design enter into the problem, all accelerating or decelerating the rate of sludge and contamination found in the lubricating oil of these engines.

Actual field records indicate that certain diesel engines in large pumping plants will make more than twice as much sludge and contamination as other engines operating in the same vicinity, doing the same work, using the same lubricant and burning identically the same fuel. It is possible with certain designs of engines in some types of operation to maintain the lubricating oil at a constant, excellent value, regardless of the length of hours of operation, by complete conditioning of the lubricating oil during use. In other cases, to maintain the oil at a satisfactory equilibrium it requires the collection and elimination of approximately five times the amount of contaminants to maintain a satisfactory lubricant specification. For methods of conditioning lubricants during use, I call your attention to a paper by the writer entitled "Modern Methods of Conditioning Lubricating Oil During Use." This paper was presented at the National Tractor Meeting of the Society of Automotive Engineers in Milwaukee, September 28, 1939. Various means have been provided to satisfactorily lubricate high speed, heavy duty engines involving various types of lubricants, compounded and otherwise.

From 30-odd years of experience in the operation and design of engines and the manufacture of lubricating systems, fuel and lubricating oil filters, etc., it is my opinion that there are a great number of good

lubricants which could be applied to any type of machinery, including steam or internal combustion engines. By the same token, I do not believe that there is any specialized lubricant that is so highly specialized that it is the only lubricant that can be used on any particular application. If such were the case, then from the engine designer's viewpoint, I would say that that particular engine is of very faulty design and construction to require such specialized wet-nursing with lubrication.

In the gathering of material used in the successful design of engines and lubricating systems, the writer has found records of engines which have operated successfully for over 200,000 miles of heavy duty operation in heavy motor vehicles with no bearing changes or difficulties whatsoever. In fact, bearings removed from one engine after over 200,000 miles of heavy duty use are still within the original manufacturing tolerance for new precision bearings. I have also uncovered cases of faulty lubricating systems and engine designs wherein engines could not possibly be operated beyond a certain rpm or certain bearing load with relatively low bmep.

In the design of filtering systems and the successful applications of filters to lubricating systems, many important considerations should be studied before any filter is applied. If the problem is to keep dirt out of bearings, then naturally the lubricant should be completely filtered before entering the bearing. This is especially true of high flow-rate lubricating systems when the lubricant is recirculated at a high flow-rate carrying with it all the collected grit and contamination which may be in the system, as well as the condensed products of combustion, etc., all of which have considerable effect of oxidation on the oil. In many cases, considerable air, in the form of foam in the oil itself, is present. This latter is especially true in the lubrication of large internal combustion engines of the dry sump type wherein the sump pump has a greater capacity than the lubricant pressure pump. Referring to Figure 8, if the lubricant pressure pump is capable of delivering 50 gallons of oil a minute to lubricate all of the bearings and also for piston cooling, only 50 gallons of actual oil will be in circulation within the engine filter and lubricating system each minute. On the other hand, if the scavenger pump which picks the oil up from the sump and delivers it to the oil reservoir has a capacity of 100 gallons a minute, it is obvious that 50 gallons of oil plus an equivalent amount of air will be pumped through the filter and into the oil reservoir each minute of engine operation. Therefore, the problem becomes one of removing and trapping air, in the form of foam, out of the oil, as well as filtering grit and contamination from the oil, all of which seriously complicates the problem of maintaining a clean lubricant during engine operation.

From observation of engine operation in various types of service, it is the opinion of the writer that the least amount of air that can be entrained with the oil by the scavenger pump is a very desirable condition. On the other hand, it has been our experience that where a large amount of air is entrained with the oil by an oversized scavenger pump, various problems are encountered, not only with the lubrication of bearings, but with filters, oil foaming problems and many other conditions too numerous to mention in this paper. It is very important, however, to call attention to the fact that an oversized scavenger pump continually emulsifying air, oil, water, etc., aids in the oxidation of the oil and, furthermore, it is my belief that corrosion and deterioration of bearings is accelerated by the process of foaming air and oil through the lubricant ducts and filter elements.

An excellent comparison with the trend of modern design to flood all of the working parts of an engine with a copious supply of lubricant, is to refer back to the system in common use in the earlier types of gasoline engines, wherein a minimum amount of lubricants was used and actually controlled by the tightness of the bearings as well as the end clearances around the fillets of the crankshaft, crankpin, bearings, etc., and not by the scraper rings on the pistons. As a matter of fact, many of the earlier engines with babbitted bearings were sent off of the production lines with the bearings actually burned in by force and they had practically no clearance for some time after being placed in operation. It was a common practice in repair shops to take a car out on the road and tow it to get it started after being overhauled, for the reason that the starter did not have enough power to move the engine because the bearings were so tightly fitted that the engine could not be rotated except by jumping on the starting crank or towing the car with a truck, etc. Under these conditions it is obvious that a very small amount of lubricant was actually forced through the bearings even by relatively high pressure. It is also quite obvious that the actual amount of oil flowing from the pump to the engine bearings was an easy matter to handle with a small full-flow, in-line filter. That is, all of the oil that passed from the pump to the bearings was filtered oil.

With the advent of so-called precision bearings and higher operating speeds with greater brake mean effective pressures, it was natural to require more and more lubricant in circulation, not only to lubricate the bearings, but to remove the heat which was generated by high rotative speeds. As these developments and increased flow-rate through lubricating systems became a fact, it was necessary to design filters with correspondingly higher flow-rates in order to handle all the oil passing from the lubricant pump to the engine bearings. It was also necessary to maintain the lubricant in a relatively clean state, free of contamination in the form of gums, varnish, grit, water, etc.

Referring to Figure 11, it is shown what usually happens when dirty oil flows through conventional lubricant

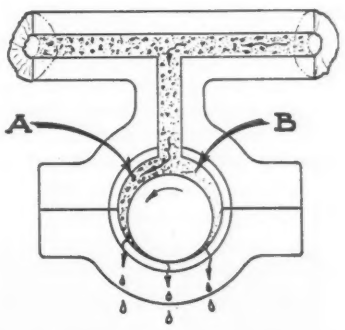

Figure 11. This figure illustrates the rock-crushing process in conventional unprotected bearings. As the shaft rotates toward (A) it crushes grit particles into the soft bearing shells permitting only the finer ones to pass through the bearing clearance toward (B).

ducts into bearings. The grit being carried along with the oil is fed into the wide clearance of the bearings on one side, illustrated by the letter (A), and ground around through the minimum clearance of the bearing to the opposite side as illustrated at (B). In actual practice all of the large chunks of grit, dirt, etc., are forced into the clearances through which the particle sizes will not pass. This process has been previously described in detail by the writer in a paper presented before the Society of Automotive Engineers, San Francisco, California, on June 8, 1943. The subject is well illustrated on Figures 1, 2 and 3 of Plate 9, on Page 4 of this paper, the title of which is "Modern Filter Development as Applied to Fuel and Lube Oil Systems of Diesel Engines." To briefly describe the rock-crushing process, it might be reiterated that all of the large hard rocks that will not fit through the minimum bearing clearance are forced into the soft bearing metal surface by the hard rotating shaft and thus impressed and held fast. These high points form excellent cutting edges to continually cut grooves in the rotating shaft for the full life of the equipment or until they are removed by scraping during overhaul process. It can be readily appreciated from the above that a high flow-rate of oil with its advantages of copious flow for heat removal also has disadvantages in carrying relative large amounts of contaminants during circulation and, therefore, filtering all deleterious matter from the lubricant, becomes a more and more important consideration as flow-rates are increased.

Lately developed compounded lubricating oil also has added some problems to the matter of keeping the lubricant clean by filtering. The very fact that certain types of compounded lubricants prevent deposits of gum and varnish by the lubricant peptizing process also brings about the problem that all the dirt, grit and other sludge formations in the oil are incidentally continually peptized and floated around through the bearing ducts rather than settling out by gravity or being trapped out of circulation in gear cases, valve covers, or being caught in filters. For instance, if the peptizing of all the contamination in an engine lubricating system is necessary to prevent the deposit of gum, varnish, sludge, etc., on certain surfaces of the engines including the gear case cover, the valve rock-arm cover, the bottom of the oil pan, the valve tappet assembly compartments, the interior surfaces of the fly-wheel housing, etc., then the elimination of this undesirable contamination from those surfaces should be weighed against whether it is better to let it lie quietly out of circulation, or to continually keep it in circulation, carrying with it all of the grit and abrasive substances normally found in the make-up of such material.

As previously stated, there are certain types of lubricants most desirable and practical for any specific requirement. When it is deemed proper to use compounded lubricants in the lubricating system of an internal combustion engine, it should be borne in mind that all the grit, sludge and gum formation normally found, plus metallic salts compounding, etc., used in the oil, are in continual circulation and the oil should be properly conditioned for the removal of the undesirable contaminants without the removal of the desirable additives. Briefly, the problem becomes one of providing a relatively high flow-rate filter which removes harmful grit, sludge, varnish, etc., and yet permits the free passage of additives in the lubricating oil.

It is a well-known fact that a good grade of lubricating oil has practically a constant lubricating value if all contamination is removed continually and the rate of removal of contamination is equal to the rate of formation. High flow-rate filters have material advantages, not only in maintaining clean lubricant in an engine but also in actual filtering efficiency. Continual and proper filtering of lubricant during use also has a material benefit on oil stability. It is extremely desirable to maintain lubricants clean and free of contaminants for the sake of long engine life and it is also important to maintain the oil clean and pure for the sake of long oil life and the maintaining of a satisfactory equilibrium lubricating value of the oil itself during use. Both of these subjects have been previously discussed in the S. A. E. Paper previously mentioned titled "Modern Filter Development as Applied to Fuel and Lube Oil Systems of Diesel Engines." On Page 7 of this paper, graphic illustrations are shown through the cooperation of Mr. R. G. Larsen, Mr. F. A. Armfield and Mr. G. M. Whitney of the Shell Development Company of Emeryville, California. Illustrations shown as Plates XV and XVI are from a paper entitled "Chemical Problems of Engine Lubrication and the Problem of Lubricating Oil Stabilization."

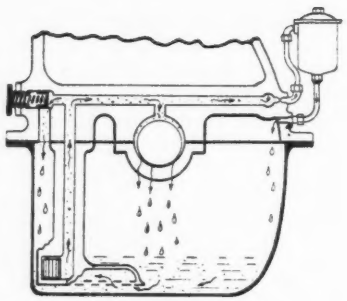

Figure 12. Conventional automatic system in which grit is forced directly into engine bearings with oil.

Quoting from this paper: *"Plate XV illustrates the rapid deterioration of lubricating oil in a relatively short time under practical operating conditions and further illustrates that adding a considerable amount of new oil to the crankcase of an engine during operating conditions does not materially aid in restoring and improving crankcase oil stability as long as some of the old oil is left in the crankcase. Plate XVI shows a remarkable comparison of how a good oil can be retained, as far as stability is concerned, by proper filtering as compared to its rapid depreciation when a filter is not used."* To summarize the situation, clean, pure oil not only protects the engine, but also protects the lubricant itself from depreciation and loss of stability.

As previously pointed out by the writer and others, filtering and conditioning the lubricant in the crankcase of an internal combustion engine certainly is desirable. Filtering all the oil passing from the pump to the bearings is also desirable. The method of arriving at an ideal system, however, must be like all engineering projects—a fair compromise between what might be considered ideal as contrasted with the best and most practical application which is justified both from an economical and design standpoint. Referring again to Figure 6, the engine bearings in this case certainly have the advantages of full pressure lubrica-

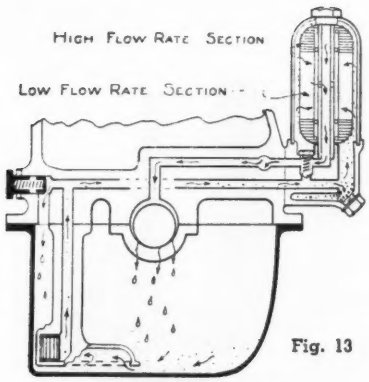

Fig. 13

Figure 13. Full-flow in-line system where grit is forced into filter sump and trapped out of circulation as it is removed from the oil.

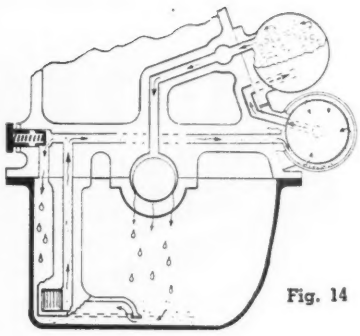

Fig. 14

Figure 14. Full-flow in-line system with oil cooler. Grit is removed from circulation and lubricant is forced to bearings clean and cool.

tion, but the disadvantages that all of the grit in circulation is forced directly into the bearings which are used as rock-crushers.

In Figure 12, a modification is provided wherein a small amount of lubricant is bled through a restriction and is continually filtered during operation, but all of the dirt still in circulation is ground into the engine bearings as before and only those particles that are not stuck in the soft metallic bearing metal shells are finally caught by the filter. I am not advocating that any filter is not an advantage; it certainly is. Any filter is better than no filter. However, the application of a filter to any lubricating system is governed by practical and economical considerations. If an engine was originally designed without full-flow filtering and no provisions made for same, then the only possible application is as shown in Figure 12, that is, to simply bleed the oil header line for as much oil as can be robbed without bearing pressure loss and filter this small part of the oil, then shunt it back to the crankcase. If the filter in this case is large enough and the flow-rate is high enough to keep ahead of the rate of dirt formation, the oil can be maintained clean indefinitely, but, as previously stated, the bearings are not protected from the entry of grit which may be picked up by the lubricant pump.

Referring to Figure 13, in this case the lubricant is picked up by the pump and forced past the pressure regulator to the sump of the full-flow, in-line filter where most of the heavy grit and dirt is dropped out of circulation by gravity. The oil must then pass upward through a filter element before continuing on to the oil header and engine bearings. It should be noted that all grit is simply trapped out of circulation either in the enlarged lower sump or against the filter element at each cycle of the oil through the system. The application of this type of filter is of primary consideration when the engine is designed and it must be an integral part of the engine and lubricating system. If so, and properly constructed, it need not have any outside lines whatsoever—the oil passages and ducts all being formed within the engine structure.

In this filter application I have also illustrated the application of a filter replacement cartridge recently developed by the writer's company. The purpose of this cartridge is to effect a fair compromise on small undersized filters between completely filtered oil and absolutely clean oil. As previously pointed out, if the filtering pressure on opposite sides of the filtering element is too high, then fine dirt, etc., may be forced through and, furthermore, a high differential on opposite sides of the filter element causes loss of pressure on the bearings. In this most recent filter cartridge, the compromise is made in the cartridge itself. That is, the cartridge has two flow-rates, a high flow-rate to insure that all of the oil reaching the bearings will be filtered oil and a slower flow-rate to insure that all of the fine dirt, soot, etc., will eventually be trapped out of circulation in the oil. The main consideration, however, is that when the engine is started with cold oil or when the cartridge is partly clogged, the bearings will always be supplied with filtered oil and the by-pass under normal operating conditions will never open, thus preventing unfiltered oil from ever passing from the lubricant pump to the engine bearings.

In Figure 14 is shown a still further improvement in conventional lubricating systems. In this case the lubricant is picked up from the crankcase sump as before, passed through a relatively coarse screen and forced up past the pressure regulator and into a large horizontal filter casing. It is filtered hot through an oversize free-flow filter element, then it passes through a heat exchanger and is cooled before being forced to the oil header and bearing lines. This is an ideal system where the lubricant can be maintained at a satisfactory stability by being continually purified during the operation of the engine. The filter as shown is of more than ample size and capacity, thus preventing the filter bypass from opening under all normal operating conditions. The engine bearings are thereby always fully protected against the entry of grit and the working surfaces are maintained at a satisfactory temperature due to the cooling of the lubricant at each cycle of operation.

Referring to Figure 15, a typical example of what happens to replacement filter cartridges in service is shown. In the first case, the filter cartridge may weigh 1 lb and when removed from the engine it may weigh 10 lbs. The collected contamination completely saturates and covers the element, building up on the outside until the flow-rate is reduced below a practical low flow limit. In Figure 1, a conventional marine propulsion reduction gear was shown, hundreds of which were built during the war. One of the developments of the writer's company was the building of filters large enough to handle all of the oil flowing from the lubricant pump to all parts of the turbine and gear reduction machinery of marine installa-

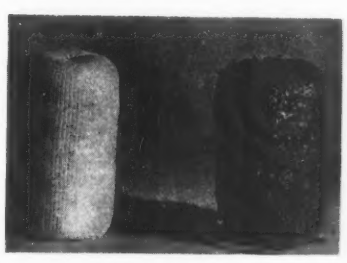

Figure 15. Typical Winslow Oil Conditioning Elements before and after use.

tions. These filters were used for flushing out all contamination, grit, moisture, etc. from new and overhauled power plants such as are used aboard battleships, destroyers, cruisers, merchant ships, etc. In this case the ship's lubricant pump forces all of the lubricant through the filters and machinery, then back to the source of supply, thus washing out and flushing all contamination and grit, etc. from the machinery that can be moved by either cold or hot oil moving at high velocity.

A filter of the general type used on these installations is shown on Figure 16. It should be noted in this case that the filter has exceptionally large exterior filtering area, and also that it has a great number of outlet pipes from the elements to the clean oil outlet section of the filter.

Figure 17 is an illustration of a battery of these high flow-rate filters capable of handling up to a thousand gallons of oil a minute of normal viscosity and at conventional operating temperatures. The head required to filter this oil under these conditions can be as low as 3 to 5 lbs differential across the filter element.

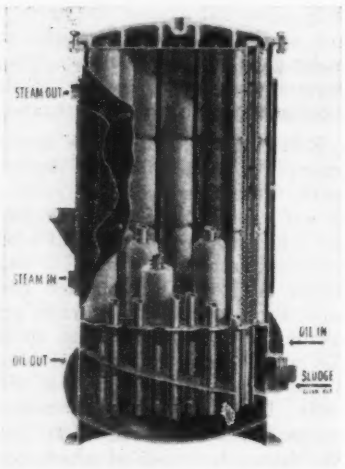

Figure 16. Six of these Giant-Flo filters containing 342 Winslow elements on a large installation are cleaning over 500 gpm of SAE 30 lubricating oil at 140 F with a pressure differential of less than 10 lb. between the inlet and outlet of the filter unit.

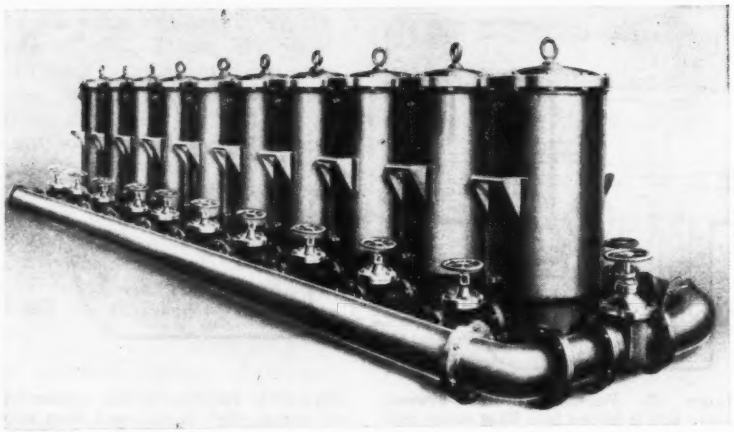

Figure 17. These Giant-Flo Oil Conditioning Units are available not only for ships but also for large industrial power units, pipe lines, etc.

Conclusion

In conclusion I might state that the developments shown are the result of a great many years of experience with problems relating to the filtering of fluids and particularly lubricating and fuel oil. It might be added that the original full-flow in-line filtering systems with filters built in as part of the engine and lubricating system are of the writer's design and covered by many of the previously mentioned patents listed below. The numbers of these patents are furnished as an additional source of technical information for those who are inclined to be patent minded. As a matter of fact, it is the writer's opinion that the United States Patent Office is the greatest library in the world on technical and scientific information. Consider for example, the thousands of recent patents contributed on the subject of fuels and lubricants in which we are all interested. For 10c a copy, any and all interested parties are entitled to a full and complete disclosure of the inventor's contribution to any art covered by patents. We can read at our leisure, the complete information that the inventor had on the subject, or at least as much information as he was willing to disclose to obtain his 17 year monopoly granted by the Government in the patent for such information.

[1] *LUBRICATING SYSTEM AND FILTER PATENTS*

1,638,281	*1,901,484*	*2,134,385*
1,659,902	*1,948,282*	*2,314,640*
1,671,391	*1,992,339*	*1,555,664*
1,780,663	*1,996,106*	*1,952,740*
1,800,625	*2,071,483*	*2,345,848*
1,892,443	*2,118,283*	*2,345,849*

(Others Pending)

Fundamentals of Lubrication

By JAMES I. CLOWER

Professor of Machine Design, West Virginia University

The importance of proper lubrication can hardly be overemphasized. This is evidenced by the many technical papers that appear each year. Unfortunately these papers do not enjoy as large an audience as they deserve, doubtless because most engineers are not familiar with the basic theory and principles of lubrication. While this paper makes no attempt to present the mathematical theory of lubrication, it does point out in words and pictures the more important basic concepts of the principles of correct lubrication, an understanding of which is essential for design and operation of modern high-speed machinery.

* * * * * * * * *

Introduction

LUBRICATION is both the art and science of reducing frictional resistance that occurs at the surfaces of two solids when they are forced to slide over each other. Any substance inserted between the two relatively moving surfaces for the purpose of lessening the friction is called a lubricant. Oils and greases are the most common examples of lubricants, but other substances are used. Different types of lubricants include: emulsions of oil and water for cutting tools; water, for some marine bearings; milk, in the bearings of cream separators; and air, in certain high-speed spindles. The lubricant often performs the added function of carrying away heat generated by friction and/or heat conducted from a source to the bearing, such as in steam turbine bearings.

From existing evidence it appears that all three of the principal classes of lubricants—animal, vegetable, and mineral—were available at an early date. Beef or mutton tallow was apparently used for lubricating the axles of chariot wheels before 1400 B.C.; petroleum refining was described by Herodotus (484-424 B.C.), and a list of the vegetable oils was compiled by Pliny (A.D. 23-79). It has even been inferred from this list that the ancients recognized the need for more viscous lubricants under some conditions, and less viscous lubricants at other times.

Although the art of lubrication has been practiced for several thousand years, understanding of the phenomenon of lubrication is a comparatively recent development and is not yet complete. Numerous papers are added to the literature each year, some offering analyses of existing problems and some posing new problems for future study and solution.

Lubrication, like every other mechanical action, is governed by Newton's laws of motion upon which the science of mechanics is based. In addition, Sir Isaac Newton (1687) discovered the fundamental law of viscous resistance underlying the theory of lubrication, according to which the shear stress is proportional to the rate of shear.

Amontons (1699) and Coulomb (1785) discovered that the coefficient of friction (ratio of tangential resistance to the normal component of the load) is constant for dry and imperfectly lubricated surfaces over a considerable range of contact area, speed, and load. Morin (1833) confirmed the Amontons-Coulomb law for a wider variety of materials, and conducted systematic experiments on journal bearings. He found that the coefficient of friction was reduced to about one-half when the lubricant was continuously supplied.

Hirn (1854) discovered the effect of running-in, and concluded that the friction of lubricated surfaces might be taken as roughly proportional to the square root of the area, load, and speed.

Thurston, an American, (1873) was a pioneer in the testing of lubricants and drew attention to the importance of reducing friction losses in machinery. He discovered the existence of a minimum point when the coefficient of friction is plotted against speed or temperature. To Thurston is due the widely quoted rule that the safe bearing load per unit area is inversely proportional to the speed. Although not applicable to modern high-speed bearings, it illustrates the need for some definite relation connecting load capacity with speed as a starting point for bearing design.

Petroff was awarded a prize by the Russian Academy of Sciences for his investigation published in 1883, in which he demonstrated the utility of petroleum oils by showing that their successful use depended merely on selecting a suitable viscosity for each application. He also deduced the first mathematical formula for the friction of a journal bearing, treating the case of a full bearing operating with a uniform film thickness.

The science of lubrication, as we understand it today, dates from the experiments of Beauchamp Tower (1883) and their interpretation by Professor Osborne Reynolds.

Tower was investigating the friction of bearings similar to those used in railway service. They were 4 in. in diameter, 6 in. long and had an arc of contact of 157 degrees. Oil was supplied first by a syphon lubricator, then by a pad, and finally by means of a bath. His results were erratic until he ran the journal in a bath; then the results were surprisingly uniform and the coefficient of friction was exceedingly low. By chance, he found that there was a true fluid pressure within the oil film. For the purpose of installing a lubricator, a half-inch hole had been drilled in the center of the brass. An outflow of oil then occurred when running the machine. To prevent it, a wooden plug was driven into the hole; and on starting up again, the plug was slowly forced out. This precise moment appears to have been the turning point in the history of lubrication. A pressure gage was attached and indicated a true fluid pressure in the film, at the center of the bearing, sometimes as great as twice the pressure computed by dividing the load by the projected area of the bearing.

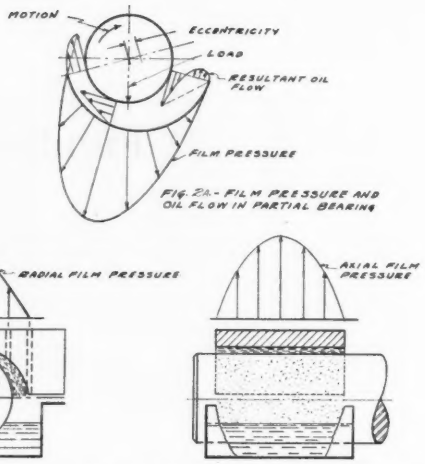

Figure 2. Pressure in Oil Film at Partial Bearing.

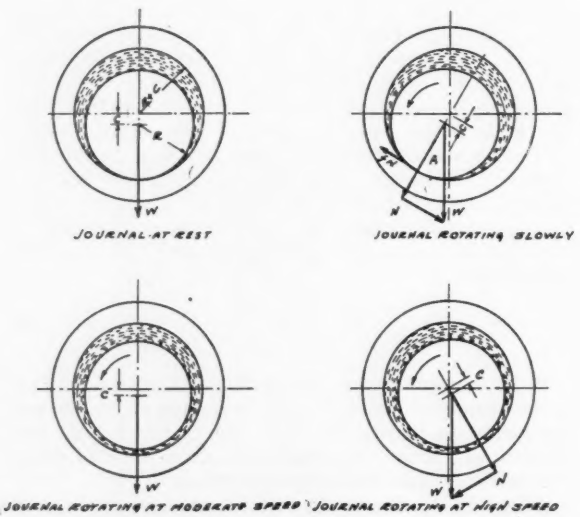

Figure 1. Step-by-Step Formation of Film in Journal Bearing.

Reynolds, at the University of Manchester, used Tower's results to show how they verified the application of the laws of hydrodynamics to bearings. He published the results of his analytical work in 1886, but their importance was not generally recognized until many years later. His classic paper contains three principal contributions: (1) a general picture of the physics of lubrication, more complete than any previous contribution; (2) an equation for the pressure distribution in the film, capable of many future applications; and (3) application to Tower's experiments. The most significant result of Reynold's theory is that of the converging film. The lubricant adheres to both the moving and stationary surfaces, and by virtue of its viscosity, develops a positive fluid pressure in the converging portions of the film. This pressure supports the load and prevents metallic contact. No such pressure can be developed between strictly parallel surfaces. Figure 1 shows step-by-step the formation of an oil film in a journal bearing. In Figures 2 and 2A are shown oil film pressure and oil flow in a partial bearing. Figure 3 shows the effect of grooving in a bearing on the oil film pressure. Shown in Figure 4 is the effect of motion on the formation of an oil film. Figure 5 shows the effect of shape on the formation of a film.

Many other men, in addition to those already mentioned, have made important contributions to the science

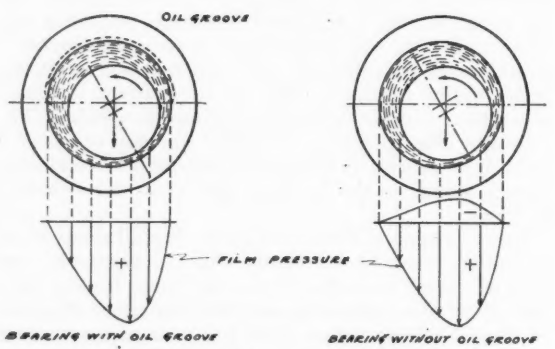

Figure 3. Effect of Oil Groove on Film Pressure.

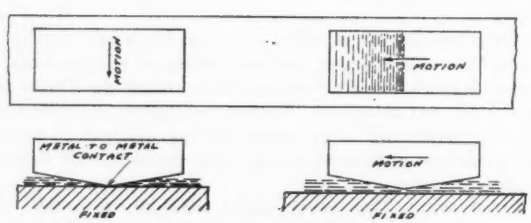

Figure 4. Effect of Motion on Film Formation.

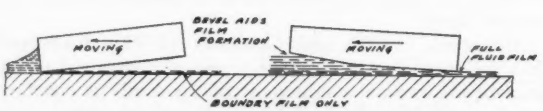

Figure 5. Effect of Shape on Film Formation.

of lubrication. It is possible, however, to mention only a few of them here. In England, W. J. Harrison and R. O. Boswell have advanced the mathematical statement of hydrodynamic theory. Boswell's "The Theory of Film Lubrication" is, perhaps, the best single statement of the hydrodynamic theory that exists today. A Sommerfield has contributed a classical analysis of journal bearings. Two other Germans, Lasche and Stribeck, have made noteworthy contributions. Lasche published the results of his experiments on oil groove bearings with different clearances in 1902. Stribeck's work on bronze and white metal bearings and his investigations of rolling bodies form the basis of many bearing designs as practiced today.

Albert Kingsbury, in America, has made a number of outstanding contributions; namely, the mechanism of lubrication of cutting tools, use of air as a lubricant, and the development of the Kingsbury thrust bearing.

Friction and Lubricants

A bearing is frequently defined as the stationary part of a machine that supports a moving member. This discussion, however, will be confined to bearings that fall into the category defined as a combination of two solids, the surfaces of which have relative motion while slightly separated by a film of lubricant. This is not a general definition, as it excludes so-called oilless bearings, antifriction bearings, gear teeth, and others. It does, however, include slipper, or sliding bearings that have parallel surfaces; thrust bearings that carry axial loads; and journal bearings.

Friction is common to all of these various types of bearings. But the so-called laws of friction vary widely in these bearings with conditions. A consideration of the laws of friction, as applied to machinery, naturally divides itself into two main divisions: boundary friction and fluid friction. Boundary friction includes: (1) dry or solid friction, which occurs between perfectly clean, dry, solid surfaces; and (2) thin-film friction, which occurs between solid surfaces partially or completely separated by a film of fluid so thin that the unknown intermolecular forces between the fluid and solid surfaces determine the character of the frictional resistance. Fluid friction includes all cases of frictional resistances between solid surfaces completely separated by a film of sufficient thickness to conform to the laws of fluid flow.

The laws of dry friction are mainly empirical and, hence, are only rough approximations. They are chiefly based on the experimental results of Amontons, Coulomb, Vince, Rennie, and others. From the results of experiments conducted in 1699, Amontons concluded that the ratio of the force resisting motion to the force normal to the sliding surfaces is constant with respect to load, speed, and area. This ratio, called the coefficient friction, varies with the materials and the nature of the surfaces, and it is sensitive to contamination of the surfaces by any substance, such as moisture, oil, grease, etc. Because dry friction causes wear and possibly seizure, or welding, of the two surfaces, it is essential that it be avoided in bearings.

Engineers are deeply concerned with thin-film friction because it is very prevalent in machine bearings. Either it must be held to reasonably close limits or else present trends of higher speeds, temperatures, and loads will be greatly curtailed. In thin-film-friction conditions, the full fluid film does not exist; consequently, the boundary layers are of great importance.

The boundary film formed by a lubricant on a solid surface has a frictional value that depends on the chemical nature of both the metal and the lubricant. Much research work has been done to determine the structure and properties of absorbed films, which adhere to solid surfaces and often increase the slipperiness of their surfaces. The slipperiness of the surface is commonly referred to as its unctuousness and the lubricating value of absorbed films as oiliness; thus, the friction of a bearing operating under thin-film conditions is due to the unctuousness of the solid surfaces and to the oiliness of the lubricant.

Thin-film friction, although widely prevalent, is not fully understood; but we do know that it involves the chemical nature of both the lubricant and the boundary surfaces. Under this condition, one kind of bearing metal may cause less friction than another, when all other conditions are held constant, and one kind of oil may cause less friction than another oil of the same viscosity. Experience shows that the so-called fixed, or fatty, oils give less friction than mineral oils under thin-film conditions. Currently, it is the custom to say that fixed oils have greater oiliness than mineral oils. The superiority of fixed oils disappears, however, when thicker films are produced at higher speeds and/or lower loads. Also, inherent lack of chemical stability and the fact that they are relatively expensive and are not obtainable in varying viscosity grades, make fixed oils and fats undesirable as lubricants for most purposes.

Herschel has defined oiliness "as the property that causes a difference in the friction when two lubricants of the same viscosity at the temperature of the film are used under identical conditions." Many oiliness investigations have been performed, but as yet no standard scale or unit has been adopted and the ability to formulate the property, as has been done for viscosity, seems to lie far in the future.

There have been many hypotheses offered in explanation of oiliness; the two most generally being adsorption and stratification. The adsorption hypotheses suggests that the bearing metals have a stronger attraction for certain types of oil molecules than for others and that molecules of these types will separate out of the oil to form a tenacious, concentrated film which will cling to the surfaces long after a hydrodynamic film has been squeezed out.

The stratification hypothesis states that oil molecules are oriented for a number of layers out from the metal surfaces and that planes of easy slip are formed between double layers. The adsorption hypothesis is supported by the fact that a small amount of a high-oiliness compound in a mineral oil will reduce thin-film friction to a value nearly equal to that obtained by the use of the pure compound.

Fixed oils have elongated molecules with two active oxygen atoms at one end known as the pole end. Metals have a strong power of attraction for these oxygen atoms, and the pole ends of the molecules are believed to attach themselves to the bearing surfaces to form a molecular layer. Upon this layer, successive lavers will be oriented with non-polar ends in contact with non-polar ends, and vice versa. Thus planes of easy slip could exist between the non-polar ends. X-Ray observations of thin films appear to support this hypothesis of stratification.

Oiliness may be a chemical property, as the above remarks indicate. Possibly, it may be caused by local

changes of physical properties. Its true nature, however, has not been definitely determined and we should keep an open mind in regard to its explanation until its true identity is proven.

When an oil film fails completely, seizure occurs, and the intermolecular forces are so strong that one surface or both are destroyed. The exact mechanics of this film rupture and subsequent seizure are not known. It is known, however, that incipient breakdown starts at one or more tiny points, called hot spots, where the temperature rises suddenly above the melting point of the metal and actual welding occurs. The cause of the hot spots, however, is not known. One theory is that the shearing or breaking off of the tiny high spots generates sufficient heat to weld the metals. Another theory has it that the hot spots are points where the intermolecular forces become so powerful that the molecules are torn out of the surfaces with a release of sufficient energy to cause welding.

Under conditions of fluid friction of perfect lubrication, the lubricant is forced between relatively moving surfaces because of its viscosity or internal friction. It is this physical property of a lubricant that renders it highly resistant to forces tending to separate its molecules, and this resistance is the cause of fluid friction. In fluid friction, the film is so thick that the molecules of the lubricant are outside the range of action of the molecular forces of the surfaces. In fluid friction, therefore, the frictional resistance is no longer affected by the chemical constitution of the lubricant or by the nature of the solid surfaces, as in thin-film friction, but is influenced only by the internal friction of the lubricant itself, which is proportional to the viscosity of the lubricant.

Viscosity is one of the more important properties of a lubricant. For fluid friction conditions, it is no exaggeration to say that viscosity is the most important property, as it determines the bearing friction, temperature rise, rate of flow through the bearing, and the load capacity of the bearing.

All fluids, whether gaseous or liquid, possess viscosity in varying degree. It is generally known that molasses is more viscous (has a higher viscosity) than water, as is evidenced by the fact that it pours more slowly and is more difficult to stir. Likewise, oil is more viscous than water, and water is more viscous than gasoline. Viscosity is the reciprocal of fluidity.

The definition of viscosity is based on Newton's law for fluid flow, which states "that at any point in a fluid the shearing stress is directly proportional to the rate of shear." Stated algebraically, Newton's law is:

$$S = \text{constant} \times R$$

where (S) = shearing stress and (R) = rate of shear, which is the relative absolute velocity divided by the thickness of the film.

When a lubricant separates two solid surfaces, one of which moves tangent to the other at rest, the layer of lubricant in contact with the moving surface is assumed to move at the same velocity as the surface; that is, there is no slip between the solid surface and the adjacent layer of lubricant. Similarly, the layer of lubricant adjacent to the fixed solid surface is assumed stationary. Between the two solid surfaces, the lubricant is considered as consisting of a series of very thin layers or laminations, each moving at a velocity proportional to its distance from the fixed surface.

Since the shear stress and the rate of shear are both constant in this case, they may be related by a factor of proportionality that will be a measure of the fluid's resistance to flow. This gives the equation:

$$S = Z\ R$$

where (S) and (R) are as previously defined and (Z) is the coefficient of velocity, or, as it is generally called, viscosity.

Since shearing stress is force divided by area and rate of shear is velocity divided by film thickness, we may write:

$$S = F/A = Z\ V/h$$

where (h) = film thickness and (V) = velocity.

Solving for viscosity, (Z), we have: $Z = \frac{F}{A} \times \frac{h}{v}$

In words, therefore, viscosity $= \frac{\text{shearing stress}}{\text{rate of shear}}$

Viscosity is a physical property of an oil just as are density, pour point, flash point, etc. It does not indicate in any manner the ability of an oil to retain its original chemical and physical properties.

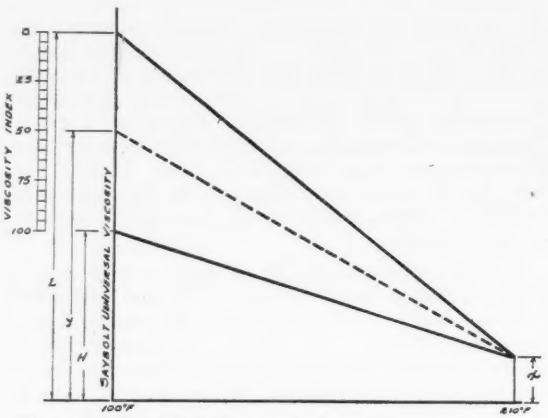

Figure 6. Graphical Representation of Viscosity Index.

The Viscosity Index is an arbitrary number that denotes the degree to which the viscosity of an oil is affected by temperature. Specifically, V.I. is a measure of the relation which the viscosity of an oil at 100 F bears to the viscosities of an average Pennsylvania and an average Coastal at 100 F, all three oils having the same viscosity at 210 F. The average Pennsylvania oil was given a V.I. of 100, whereas the Coastal oil was given a V.I. of zero.

Viscosity index may be determined in at least three ways: (1) by formula, (2) by nomographic charts, and (3) by graphical calculations. The easiest method is that of the chart. The use of Dean and Davis formula is simple but involves the use of tables prepared by them.

The principle of determining the V.I. is illustrated in Figure 6. From this chart the V.I. is obtained from the formula:

$$\text{V. I.} = \frac{100\ (L - Y)}{L - H}$$

High V.I. oil does not tend to thin out so rapidly as does one of low V.I. for the same temperature change.

For many applications oils of high V.I. are desirable, but they are not necessary in all cases. A high V.I. is desirable where an oil is required to render lubrication over a comparatively wide range of temperature. Obviously, under constant or nearly constant temperature

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conditions the use of a high V.I. oil is not necessary or important. It is fallacious to assume that an oil of zero V.I. lacks lubricating value.

The science that deals with the intrinsic flow properties of materials is known as rheology. A material may be defined in a rheological sense by a graph. A Newtonian liquid is a material whose shear behaviour can be represented by a straight line passing through the origin. Its viscosity, (S/R), and fluidity, (R/S), are constant at all values of shear stress for any given pressure and temperature. Most lubricating oils belong to this type of liquid. The hydrodynamic theory of lubrication presupposes such a material, and hence it is of primary interest in the study of lubrication. We may draw a partial analogy between a Newtonian liquid and an elastic solid following Hook's law. The law for a Newtonian liquid is $(S = ZR)$. Hook's law states that $(S = G \times a)$ where (a) is the angle of deformation and (G) is a constant for the material, called modulus of shear, or modulus of rigidity. However, (R) involves time whereas (a) does not. Also, when the stress is relieved, an elastic solid recovers its original form with practically no loss of energy, whereas in the liquid all work of deformation is lost in the form of heat energy.

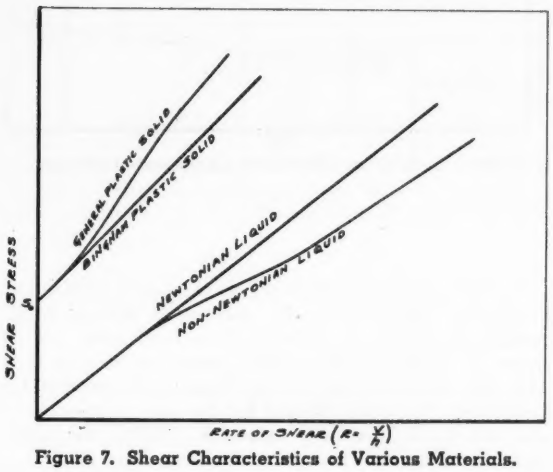

Figure 7. Shear Characteristics of Various Materials.

A Pascal liquid is one that has no viscosity. It may be thought of as an ideal liquid not found in nature. Non-Newtonian liquids are represented by a non-linear curve passing through the origin, as in Figure 7. They are complex liquids, such as rubber suspensions and certain synthetic oils. Materials whose graphs have intercepts on the shear-stress axis are known as plastic solids. They require an initial value of shear stress (S_0) known as the yield shear stress to start the flow. If the plastic solid has a straight-line relationship, it is called a Bingham solid. Greases are plastic solids, and generally considered to be of the Bingham type, although the flow characteristics of such lubricants are not yet fully known. The word consistency is generally used to denote the ratio of shear stress to rate of shear in the case of plastic solids, the term viscosity being restricted to liquids. In Figure 8 is shown the shearing of an oil film between two parallel surfaces.

Mathematics of Friction

Both theory and practice indicate that the dimensionless expression (ZN/p) is of special significance in the

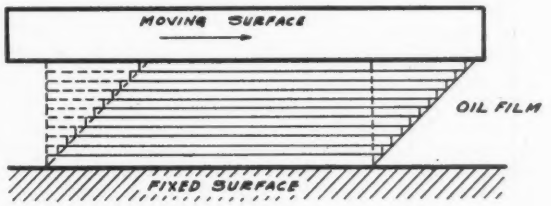

Figure 8. Simple Viscous Shear Action.

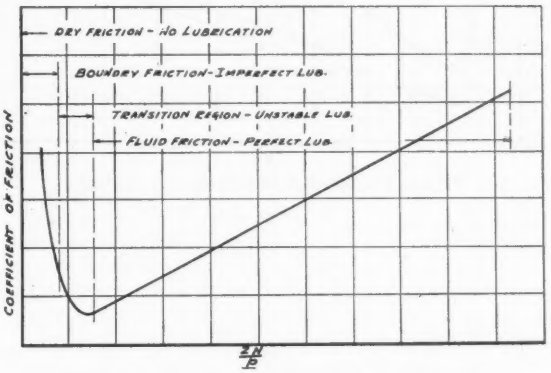
DRY FRICTION - NO LUBRICATION
BOUNDRY FRICTION - IMPERFECT LUB.
TRANSITION REGION - UNSTABLE LUB.
FLUID FRICTION - PERFECT LUB.
COEFFICIENT OF FRICTION

Figure 9. Typical Plot of Bearing Performance.

case of bearings. If a bearing is tested under various conditions of load, speed, and temperature, a plot of the observed coefficient of friction against corresponding values of (ZN/p) gives a curve as in Figure 9. As shown, certain well-defined regions of various types of friction and lubrication are exhibited. For very small values of (ZN/p), the oil film is very thin and the bearing operates in the region of boundary friction. In this region the friction is dependent on the unctuousness of the metal surfaces and the oiliness of the lubricant. In the transitional region, the film is thicker than it is in the region of boundary friction and oiliness and unctuousness play a lesser part and viscosity a more important part in the boundary-friction region. The curve is essentially a straight line and friction is entirely dependent on viscosity in the fluid-friction region.

Friction force = coefficient of friction x load or $F = f \times W = f \times p \times A$ where (A) is the projected area of the bearing and (p) is the pressure per sq. in. of projected area. Putting this value of (F), and $(V = \pi DN)$, in the equation $(F = ZVA/h)$ and solving for (f) we have $(f = C \times ZN/p)$, where $(C = \pi D/h)$, a constant for any given bearing.

The shape of the curve, $(f$ vs $ZN/p)$, will always be similar, but each bearing of different physical dimensions will have a characteristic curve of its own. The coefficient of friction depends not only on viscosity of the oil, the speed of the journal, and the load, but also on the diameter and film thickness. The thickness of the film, in turn, depends on clearance, load, speed, length-diameter ratio, and the viscosity. The effect of clearance is shown in Figure 10 and that of length-diameter ratio is shown in Figure 11.

It has long been recognized that bearings often improve with use. This is attributed to the smoothing of the surfaces so that high spots can no longer strike each other and rupture the oil film. Theory indicates that when the surfaces are completely separated by a thick

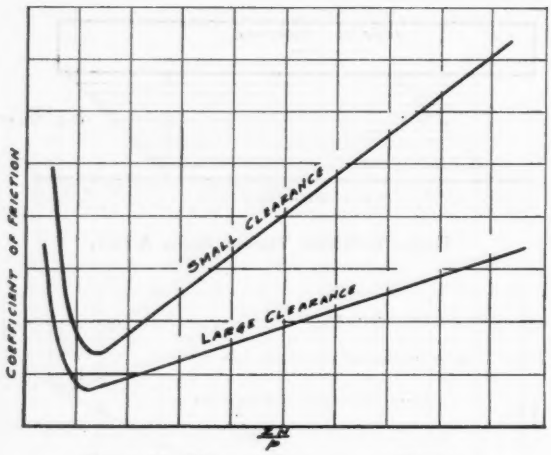

Figure 10. Effect of Clearance on Friction

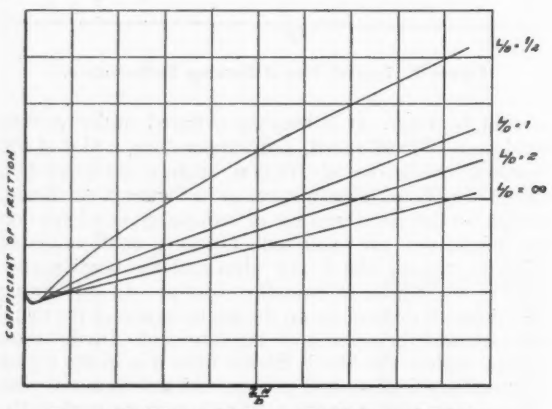

Figure 11. Effect of L/D on Coefficient of Friction.

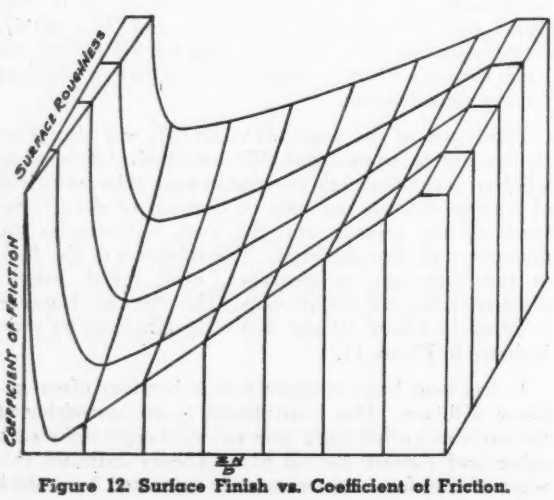

Figure 12. Surface Finish vs. Coefficient of Friction.

film the surface finish should not influence the friction, and this has been well substantiated by experiment. Surface finish, however, has a marked effect in the boundary-friction region. Not only will a smooth surface give lower thin-film friction for a given value of (ZN/p), but it will shift the minimum point of (f vs ZN/p) curve to the left.

Figure 12 shows the effect of surface finish in the form of a three-dimensional diagram. Where the finish is smooth, thick-film lubrication can be supported to very low values of (ZN/p), and the transition from thick-film to thin-film lubrication is sharply defined. As roughness increases, the minimum point shifts to higher values of (ZN/p) and (f), and it is less clearly defined, and the friction in the region of boundary lubrication is greatly increased.

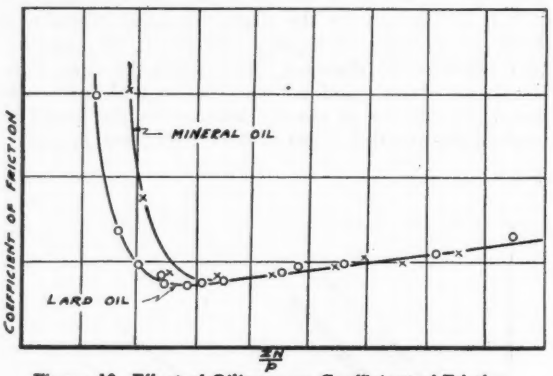

Figure 13. Effect of Oiliness on Coefficient of Friction.

If one is no longer dealing with thick-film lubrication, it may be expected that the parameters derived by dimensional analysis of hydrodynamic lubrication will no longer be sufficient for plotting results of bearing tests. That this is true is seen from Figure 13, showing the coefficient of friction plotted for two oils, a mineral oil and a lard oil. For high values of (ZN/p) the agreement is very good, but for values less than 35, (f) is no longer solely dependent on the value of (ZN/p), but upon oiliness.

In Figure 14 is shown the effect of two different bearing materials upon the coefficient of friction in the

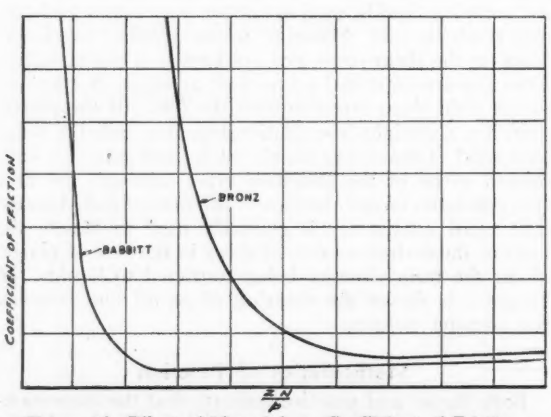

Figure 14. Effect of Material on Coefficient of Friction.

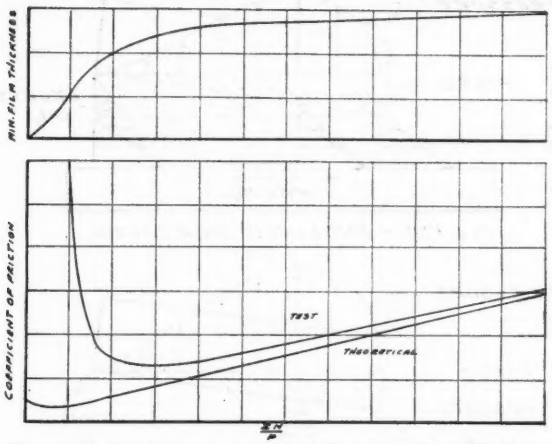

Figure 15. Performance of Journal Bearing—Fluid Friction.

region of thin-film friction. Materials have no effect on the coefficient of friction in the region of thick-film friction.

Figure 15 shows data plotted from results obtained by the McKee Brothers of the National Bureau of Standards, and, also the theoretical curve obtained from Somerfeld equation; namely,

$$\left(\frac{r}{c}\right)f=\phi\left[\left(\frac{r}{c}\right)^2\frac{\mu N}{p}\right]$$

where (ϕ) indicates some functional relationship. This equation neglects end leakage as is evident by the fact that no factor representing the length of the bearing is included. This doubtless accounts for the difference indicated on the graph between the test results and the calculated values.

In the case of fluid friction, when the surfaces are completely separated by an oil film of sufficient thickness to obey Newton's law of fluid flow, there is built up in the oil film a pressure that supports the bearing load. Shown in Figure 16 is the current generally accepted idea of a complete oil film separating two parallel surfaces. The complete film is considered to comprise an absorbed film, boundary film, and a fluid film. Within or as a part of the boundary film is the Langmuir layer of one molecule thickness. In Figure 8 is shown the mechanism of the shearing action of an oil film between parallel surfaces. Between the two surfaces the lubricant may be considered as consisting of a series of very thin layers or laminations, each moving at a velocity proportional to its distance from the fixed, solid surface.

In Figure 17A are shown two parallel plane surfaces of unlimited length and breadth, which are separated by a film of oil of (h) thickness. Plane (CD) is fixed, whereas plane (AB) moves parallel to (CD) with a constant velocity (V) in the direction of the arrow. The velocity varies uniformly from (V) at (AB) to zero at (CD); that is, the rate of shear of the oil film is constant.

When (AB) is first set in motion, the inertia of the oil prevents it from assuming a steady condition of flow. After a very short time, however, the velocity of the oil at any plane becomes proportional to the distance from (CD). Under these conditions there is no pressure built up in the oil film, and, hence, no tendency to push the surfaces apart. If, however, a load were applied in such a manner as to reduce the thickness of the oil film, a pressure would be produced in the oil film by virtue of the viscosity of the oil.

The surfaces in Figure 17B are of finite dimensions. (AB) is assumed to be flooded with oil and moving parallel to (CD) at a constant velocity (V). Prior to reaching point (D), the whole oil film covering (AB) is moving with the same velocity as surface (AB), as shown by the velocity rectangle (a b c d). On reaching (D), however, the oil film is distorted. The layer of oil coming in contact with (CD) comes to rest, and the remainder is caused by its inertia to enter the space and flow in such a manner that the rate of shear becomes much greater near (CD) than near (AB). Because of viscosity, the rate of shear of the film tends to become equal at all points and is constant at the exit end (AC). Under these conditions, the line (ED) is curved and the volume of oil entering between the surfaces is greater than that leaving at (AC). The excess oil flows out in a direction perpendicular to the plane of the paper. This flow is commonly called end leakage.

Because of this inertia effect, a pressure is built up in the oil film, which pressure is a function of the density and viscosity of the oil and the velocity of (AB). It is quite small and will not support a heavy load.

Shown in Figure 17C are two parallel surfaces (AB) and (CD), which are assumed to be of unlimited length in a plane perpendicular to the paper. Surface (CD) is fixed, whereas (AB) is moving, as indicated by the arrow, perpendicular to (CD). The oil is squeezed from the surface, and in consequence of its viscosity a pressure is created in the oil film. This film pressure is a maximum midway between (AC) and (BD), and the oil will flow equally from the midpoint to the right and left.

The curved lines indicate the flow of the oil, and the slope of these lines represents the rate of shear of the oil film at the different points. Because a force is required to maintain the rate of shear at each point constant, a vertical load can be supported.

In Figure 17D, we have a plane surface, of unlimited length and breadth, moving in the direction of the arrow, below the inclined surface of limited extent. Neglecting the inertia effect, the volume of oil carried into the space by viscous drag is proportional to the area of the right-hand triangle, whereas that discharged is proportional to the left-hand triangle. The excess volume carried into the space is squeezed from the surface in a direction at right angles to the motion of the lower surface. By virtue of its viscosity, the oil resists this squeezing action and, in consequence, a pressure is created in the film as indicated by the pressure curve.

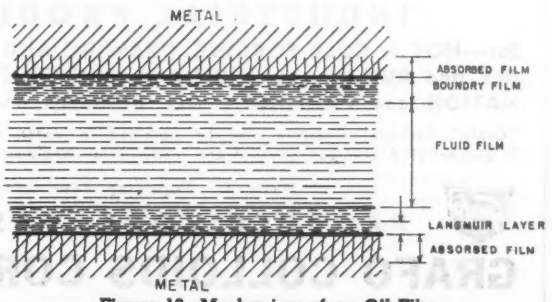

Figure 16. Mechanism of an Oil Film.

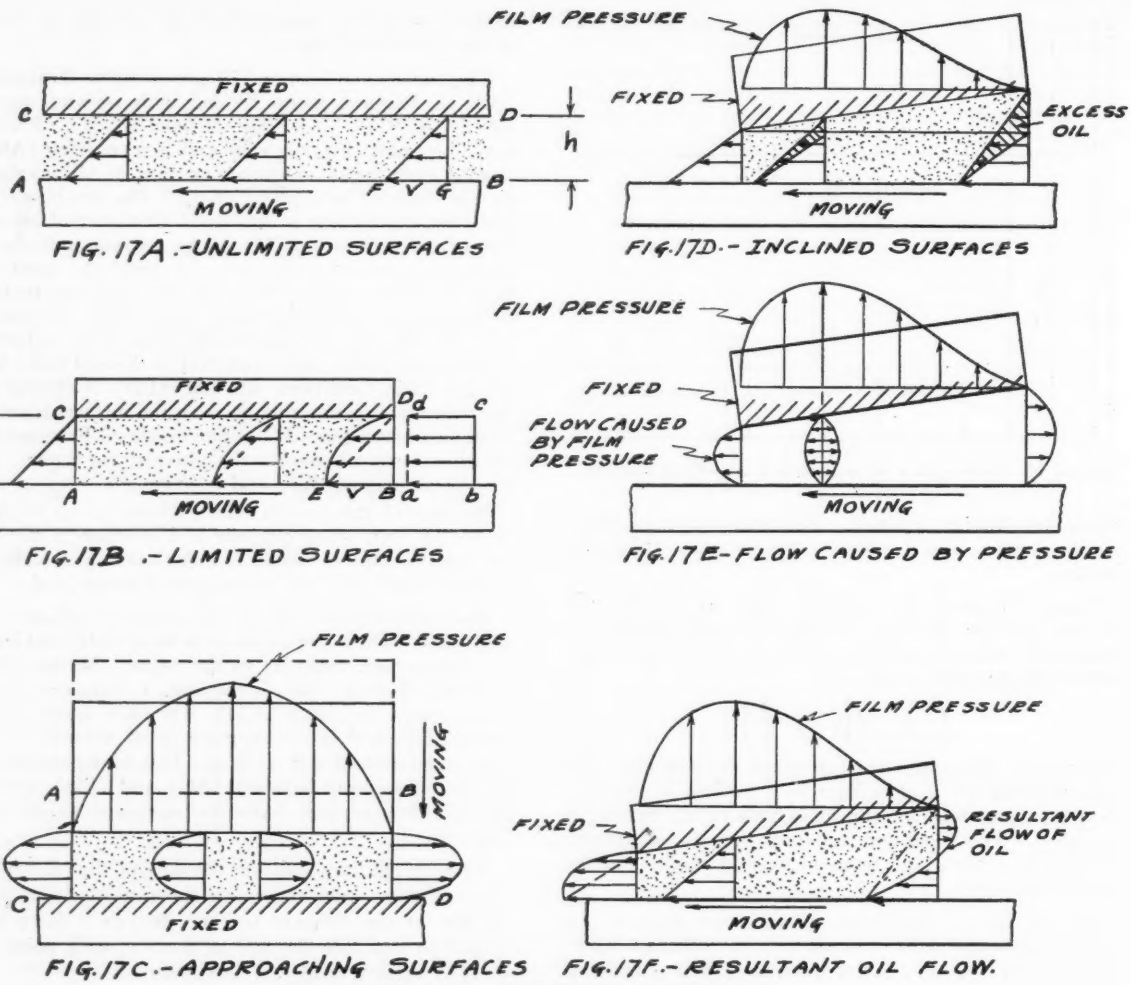

Figure 17. Mechanism of Oil Film Pressure Formation.

This film pressure tends to cause the oil to flow in all directions from the point of maximum pressure. The flow of oil caused by the film pressure alone is shown in Figure 17E. The resultant flow actually occurring is that produced by the combined action of viscous drag and oil film pressure, as shown in Figure 17F. Because the oil escapes much more freely at the entrance end than at the exit end, the general character of the pressure curve is as shown above the figure.

When such surfaces are free to assume any position, as in the Kingsbury thrust bearing, the oil-film pressure, the inclination of the surfaces, and the position of the resulting force adjust themselves to balance the load. For a given velocity, the nearer the surfaces approach each other, the greater are the friction and the oil-film pressure.

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Measurement of Lubricant Film Strength In the Region of Boundary Friction*

PART I

By VICTOR A. RYAN

Director of Research for The Crown Cork and Seal Co., Baltimore, Md.

Overcoming shortcomings of conventional types of seizure tests in testing lubricants' resistance to boundary friction, the author relates in this article how, using the Falex Lubricant Testing Machine, he standardized the machine variables and introduced wear measurements in their relationship to pressure and applied loads to obtain reproducible and consistent results. This method has proved successful in the evaluation and specification of oils for the drawing of metal and for cam and roller lubrication under extreme conditions for the past five years and should prove of great interest to operators of moving devices that work under abnormally high loads, speeds and temperatures.

* * * * * * * * *

Introduction

FOR the past ten or more years, engineers have been deeply concerned with the problems of boundary friction which present themselves in the lubrication of moving devices that operate under abnormally high loads, speeds, and temperatures. Progress in this particular field has been seriously handicapped by the lack of suitable test methods. Although the research works of many scientists have provided us with a fairly accurate knowledge of the mechanism of boundary films, no one has yet devised a method which will accurately evaluate lubricants with respect to their probable performance in actual boundary friction service.

The problem of developing an indicative test method is a scientific one demanding the cooperation of the physicist and chemist with the engineer to aid him in quantitating his lubricants. The greatest aid to an engineer in his development and control work is knowledge and information concerning methods of tests for determining the important properties of his engineering materials. Standing high among the important properties of lubricants is the ability to resist or overcome boundary friction. Consequently, any information, no matter how general in nature, concerning the measurement of this specific property must be considered a valuable contribution.

As a contributory presentation the author has selected for description a method for the measurement of lubricant film strength in the region of boundary friction which has been successfully used for the past five years in the evaluation and specification of oils for the drawing of metal and for cam and roller lubrication under extreme loads.

Regions of Friction

When lubrication is such that relatively moving surfaces are completely separated by a fluid film of sufficient thickness to follow Newton's law of fluid flow† and the surface load is supported entirely by the hydrostatic pressure built up in the film, bearings and other moving devices operate in the region of fluid friction which is also known as the range of hydrodynamic lubrication. In this region, friction and temperature rise are due solely to the viscosity of the lubricant film and are not affected by the chemical constitution of the lubricant or the nature of the solid surfaces with which it is in contact.

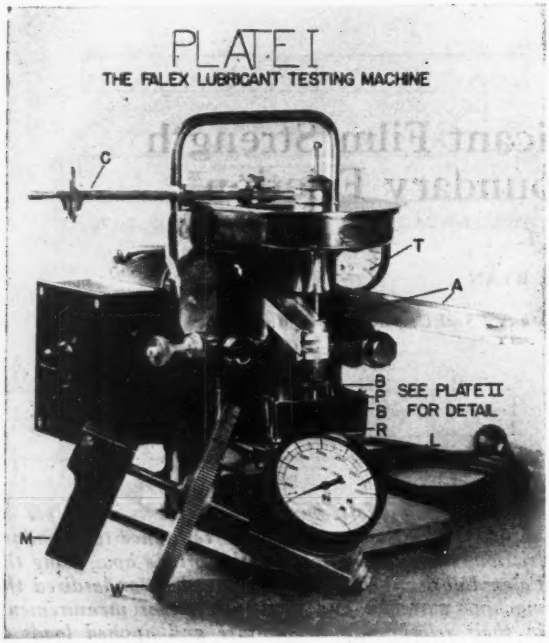
When, however, operating conditions with respect to loads and speeds are such that a state of hydrodynamic lubrication cannot be maintained and moving surfaces come into actual contact, devices operate in the region of boundary friction which is also known as the range of boundary lubrication. In this region, most of the frictional resistance is caused by the intermolecular forces of the opposing solid surfaces coupled with some interlocking of asperities.

Under boundary conditions a full fluid film does not exist by reason of its having been forced out by pressure; consequently, moving surfaces are separated and lubrication is supplied by thin films which form on the metal surfaces by adsorption and which are known as boundary films or layers.

The high pressures encountered in boundary friction place loads upon straight mineral oils which they cannot sustain unless their natural qualities are augmented with additives. Additives are usually of such chemical constitution that they readily form adsorbed boundary films either by orientation of their polar molecules or by chemical reaction with the metal surfaces to form inorganic salts or, more likely, complex organic salts of the metal. The concept in boundary lubrication is that the adsorbed film reduces friction and supplies so-called oiliness by orientation of polar molecules while it prevents seizure

† *Newton's law for fluid flow states that at any point in a fluid the shearing stress is directly proportional to the rate of shear. This is also the definition of viscosity.*

* *Presented at the First Spring Meeting of the American Society of Lubrication Engineers, Chicago, Illinois, April 5 and 6, 1946.*

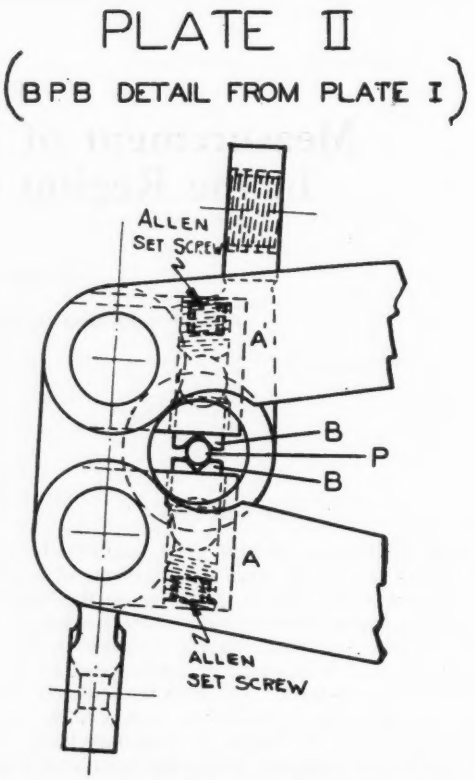


and welding by chemical combination of its reactive constituents with the surface layers of metal.

In this region of friction, the fact has been well established that the boundary layer immediately attached to the metal is of one-molecule thickness. It is known as the Langmuir layer, in which the thickness of the oil film is the length of the hydrocarbon chain. The hydrocarbon chain is naturally in an upright position by reason of its having been perpendicularly oriented. Depending upon the particular type of additive present, the thickness of the monomolecular layer will lie between the limits of 4.4×10^{-8} and 16.1×10^{-8} inches.

The frictional value of a boundary film formed on the surface of a solid is dependent upon the chemical nature of both the metal and the lubricant and is influenced to some extent by viscosity. Even under the most severe conditions all of the bulk oil is not removed by pressure and, consequently, viscosity effects are not totally eliminated. In fact, any increase in the viscosity of the very thin films of oils within the range of boundary lubrication lowers the friction, which is the opposite of the situation for thick film hydrodynamic lubrication. Another frictional characteristic also appears to be opposite; namely, the reduction of friction with increasing unit pressure. These phenomena strongly suggest that the diminution of friction is due to the adsorption of the active constituents of the additives contained in a lubricant on the surface of the metal forming a composite surface of lower energy which offers less resistance to tangential movement and has less tendency to grip or seize.

All lubrication under boundary friction conditions is associated with dimensional quantitative wear which increases with increasing loads. There appears to be no functional relation between friction and wear. In fact, in this region, which is characterized by surface contact with actual wear, the friction is less than it is in regions of fluid film friction where there is no metal-to-metal contact and, consequently, no wear. Under these circumstances, boundary lubricants cannot be properly rated or accurately evaluated solely in terms of frictional resistances or coefficients. Wear is an inherent characteristic



of boundary friction and its magnitude varies with pressure, speed, and temperature. The only satisfactory method of test that will provide an indication of what might reasonably be expected of a lubricant in boundary friction service, appears to be one that measures wear and its relation to pressure, temperature and other variables.

Methods of Testing

The Falex Lubricant Testing Machine

The majority of extreme pressure testing machines in use at the present time have been designed primarily to measure the load-carrying capacities of lubricants by a test procedure in which a load is increased at a predetermined rate until ultimate failure occurs usually by seizure or welding of the test pieces. Many variables are encountered in this seizure type of test which account for the prevailing confusion about testing machines and their inability to always rate lubricants in the same order and to rarely rate them in the precise order which actual service tests have determined. Furthermore, it is extremely difficult to obtain reproducible results in any standard test machine when the conventional seizure type of test is used. The shortcomings of this type of test are mainly due to the fact that the procedure failed to recognize the effect of dimensional wear on the relation between pressure and applied load. When wear measurements are included in the test method, some interesting phenomena present themselves. These will be discussed later.

For the study of wear in conjunction with pressure and applied load, the author prefers to use the Falex Lubricant Testing Machine* because it possesses a high

* *The Falex Lubricant Testing Machine is manufactured by Faville LeVally Corp., 105 W. Adams St., Chicago 3, Illinois.*

degree of flexibility with respect to operating technique which permits direct micrometer measurements of wear to be made without stopping the machine.

This machine is shown in plate I. It is essentially a device in which a pin "P" is rotated between two V-shaped bearing blocks "B," which are immersed in an oil cup "R" containing 55 cc of the lubricant which is to be tested. The bearing blocks are inserted in self-aligning recesses in the short lever arms, or jaws, of the load-applying mechanism. Pressure is applied through the loading mechanism "M," "W," "L," which fits loosely over the bifurcated ends of the long lever arms "A." The ratchet wheel "W" is turned up by hand until the loading mechanism takes hold, which is indicated by registration of applied load on gauge "L." Additional load is applied by engaging the load-applying arm "C" with the ratchet wheel "W." The eccentric motion of the load-applying arm "C" increases the application of load one tooth at a time. The action is similar to that of a mechanically operated nutcracker. The entire mechanism is free to swing about its axis, this tendency to turn being resisted by the sylphon operated gauge "T" which registers torque in lbs-inches. The machine operates at a speed of 290 rpm.

Standardization of Machine Variables

In all lubricant testing machines of the extreme pressure type there are usually variables which influence the test results. Unless these variables are standardized, reproducible results cannot be obtained.

In discussing boundary friction it was pointed out that the frictional value depends as much upon the chemical and physical properties of the metal surfaces as it does upon the lubricant itself. Throughout the entire region of boundary friction the actual lubricant film appears to be a complex structure of oil and metal. Consequently, the metallic test assembly of any machine must be standardized with respect to its chemical composition and metallurgical characteristics.

After numerous tests on many compositions of steel, it was determined that the most reliable and consistent results were obtained on the Falex test assembly with SAE 2320 steel for the blocks and SAE 3145 steel for the pins. These steels have a Rockwell "C" hardness of 25 and 3, respectively.

Inasmuch as the wear under boundary friction conditions is attributed to asperities, it is necessary to remove abnormal imperfections from the surfaces of the test blocks in order that the test may proceed with smooth rubbing surfaces, thereby eliminating the variation that would be caused by interlocking projections. Although the faces of the test blocks are finish ground, it has been found necessary to polish them before use. This is conveniently done by hand honing the block faces with a ⅜" square hard fine-grain Arkansas stone.

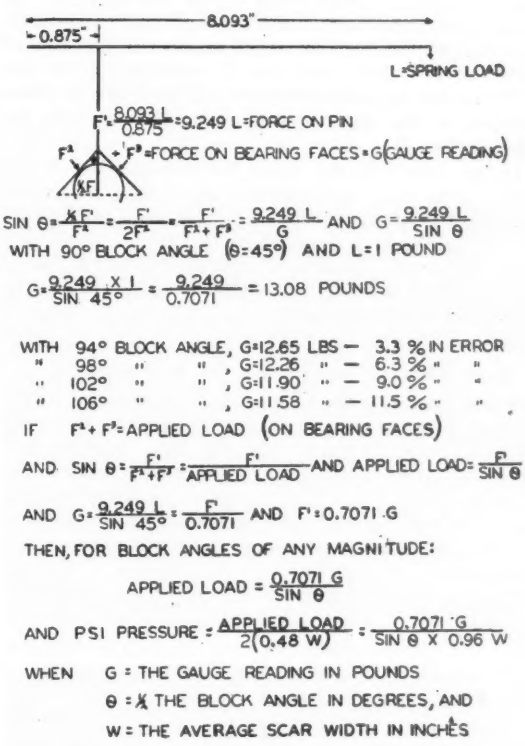
The pins receive no polishing treatment. The test starts with a 3-minute run-in period, which is sufficient to remove surface defects from the pin and, at the same time, further smooth-out the block faces.

The most influential variable and the one which requires the most accurate standardization is the angle of the test block. The extent to which test results are influenced by the magnitude of the block angle is shown by the mathematics of plate III.

Force is applied to the faces of the test blocks by the long arms "A" (plate I) through the principle of a lever of the second class in which the resistance arm is situated between the fulcrum and the effort arm.

PLATE III

FALEX MATHEMATICS


8.093"
0.875"
L=SPRING LOAD
F'=8.093 L/0.875=9.249 L=FORCE ON PIN
F₂ + F₃=FORCE ON BEARING FACES=G(GAUGE READING)
½F'
SIN θ=½F'/F₂=F'/2F₂=F'/F₂+F₃=9.249 L/G AND G=9.249 L/SIN θ
WITH 90° BLOCK ANGLE (θ=45°) AND L=1 POUND
G=9.249 X 1/SIN 45°=9.249/0.7071=13.08 POUNDS
WITH 94° BLOCK ANGLE, G=12.65 LBS — 3.3 % IN ERROR
" 98° " " , G=12.26 " — 6.3 % " "
" 102° " " , G=11.90 " — 9.0 % " "
" 106° " " , G=11.58 " — 11.5 % " "
IF F₂+F₃=APPLIED LOAD (ON BEARING FACES)
AND SIN θ=F'/F₂+F₃=F'/APPLIED LOAD AND APPLIED LOAD=F'/SIN θ
AND G=9.249 L/SIN 45°=F'/0.7071 AND F'=0.7071 G
THEN, FOR BLOCK ANGLES OF ANY MAGNITUDE:
APPLIED LOAD=0.7071 G/SIN θ
AND PSI PRESSURE=APPLIED LOAD/2(0.48 W)=0.7071 G/SIN θ X 0.96 W
WHEN G=THE GAUGE READING IN POUNDS
θ=½ THE BLOCK ANGLE IN DEGREES, AND
W=THE AVERAGE SCAR WIDTH IN INCHES

The manufacturer supplies the Falex machine with the load gauge calibrated to read directly in total force on bearing faces ($F_2 + F_3$) when the block angle is 90 degrees. Under these conditions, each pound of load applied to the spring "L" exerts a total force of 13.08 lbs. on the bearing faces and registers the same force on the dial of the load gauge. The load gauge is actuated directly by the load-applying spring "L." This arrangement produces a load-gauge reading of 13.08 lbs. for every pound applied on the spring regardless of the magnitude of the block angle. Therefore when the block angle varies, the total force on the block faces will also vary but the load gauge will remain constant and introduce an error into the measurement. For example, with a block angle of 106°, a load of one pound on the spring will exert a total force of 11.58 lbs. on the block faces and register a total force of 13.08 lbs. on the load-gauge dial, thereby introducing an error of 11.5%.

For quite some time the author has been making his own blocks with angles accurately cut to 90 degrees, plus or minus ½ degree, in order to maintain uniformity in the test methods. Formerly, the test blocks, as received, varied between 94 and 106 degrees in their angles and, to further complicate matters, there were times when wide differences were found between the angles on the respective ends of the same block.

It is not necessary for anyone to make blocks provided angles are accurately measured and blocks grouped into pairs in which the angles are equal to within one degree; and provided the magnitude of the angle is used in the equations of plate III for computing the applied load and psi pressure.

Angles can be very accurately measured on any precison optical contour comparator with a range of magnification in the neighborhood of 40-x or 50-x.

It is understood that some of the earlier Falex (or Cornell) machines were furnished with load gauges calibrated on the basis of 86° block angles. In any case of this kind, it is only necessary to substitute 0.682 for 0.7071 in the equations of plate III in order to place machines of this type on a comparable basis with the latest machines.

Having indicated the principal variables which adversely influence test results and having described methods of treatment to obtain satisfactory metallurgical characteristics and geometric compensations for the test pieces, it is now possible to operate the test machine with a high degree of accuracy in terms of consistency and reproducibility of results.

One Minute Transition Load Step-up Test

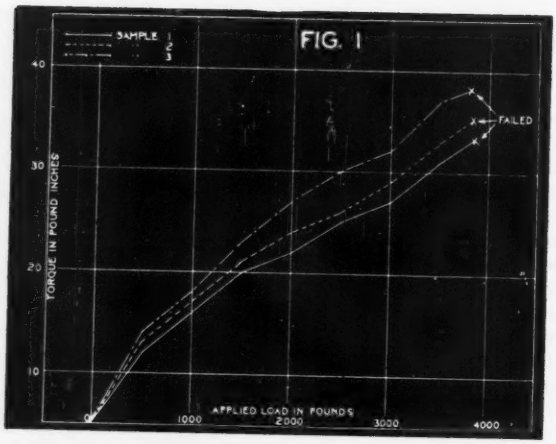
This is essentially the conventional Faville Le Vally[1] test designed to show the relation between applied load and wear during the test. On the Falex machine, the cam-driven arm acting upon the toothed wheel to increase the applied load one tooth at a time furnishes a convenient and accurate means for measuring journal and bearing wear in terms of tooth take-up on the ratchet wheel. The ratchet wheel is virtually a micrometer which measures wear in increments of .0000556" per tooth.

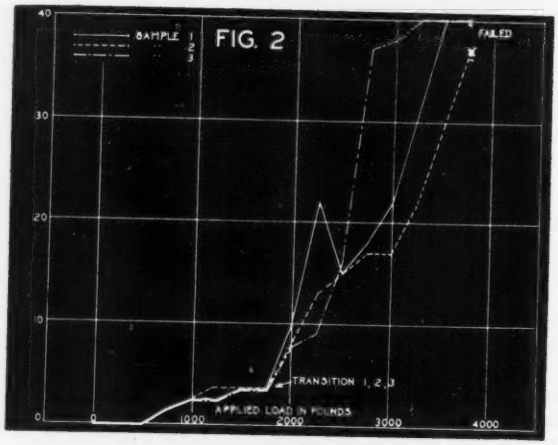
The test is also designed to show the relation between torque and load. Unfortunately, the torque mechanism of the Falex machine is not sufficiently sensitive to accurately measure the moment of friction in scientific units, but its sensitivity and accuracy are such that torque readings indicate a trend which can be relied upon to show relative frictional characteristics.

This one-minute step test is used for the routine control of purchased and manufactured lubricants, for the rating of samples in the order of relative practical worth, and as an essential part of the three-minute step test which will be described later.

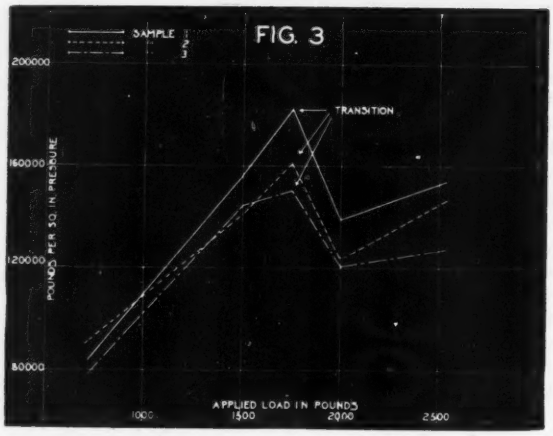
The one-minute step test is performed by placing a pre-treated, or standardized, test assembly in the machine and starting the application of the load after the oil attains a predetermined starting temperature. When the jaw load reaches 500 lbs, the load arm is lifted off the ratchet wheel and the test specimens are run-in for 3 minutes. At the end of 3 minutes, the load is increased to 750 lbs and held there for one minute by lifting the load arm off the ratchet wheel. At the end of each minute, the load is increased by 250 lbs and similarly held for one minute until the test specimen fails or the machine reaches full capacity before failure. Both torque and wear are recorded for each test load.

The wear is measured by a rather unique laboratory technique which an operator readily develops after a few trial runs. It involves no more than coordination of eye and ear. At the beginning of the test when loads are low, it will be observed that the indicator on the load gauge begins to move immediately on placing the load arm on the ratchet wheel. As the load increases it will be apparent after each successive increment that. when the load arm engages the ratchet wheel, there is a lag and the ratchet will "click" several times before the indicator on the load gauge moves. The click if the sound of the load arm pawl engaging a tooth on the ratchet wheel. Therefore, each click is equivalent to one tooth, or .0000556", of wear. At the end of each increment of load, the number of clicks are counted and recorded as tooth wear. It will be noted during the test that the number of clicks between successive load increments is approximately the same until a critical load, which differs with different oils, is reached. At the first increment beyond this critical point, the indicator on the load gauge usually drops below the reading at the start of the run and, when the load arm is placed back on the ratchet wheel, the number of clicks





Vertical Axis Shows Wear (Teeth)



before the indicator reaches the load at which it started is from three to eight times as many as the previous or critical increment. At all loads beyond the critical, the number of clicks is rather ununiform and has a tendency to increase with increasing loads.

The existence of a critical point in lubricant films under load was first described by Crowley and Faville[2] who termed it transition pressure and proceeded to show that, on repeatedly testing the same sample, complete coordination of test results was obtained up to the transition pressure and, beyond this point, no coordination was found to be possible. Continued researches were sufficiently convincing to permit the reasonable assumption that a lubricating film is maintained only up to the point of transition. At the point of transition, the film fails and permits metal movement at an abnormally high rate. This led to the logical conclusion that consistent and reproducible test results can be obtained up to the point of transition only and that tests carried beyond this point would be merely an attempt at the evaluation of metallurgy.

There can be no doubt now as to the reason why present test methods fail to properly rate and evaluate samples. The answer lies in the fact that the conventional run-up seizure type of test, without recognition of this critical point, runs to completion in the region beyond transition where it is impossible to obtain consistently uniform results. It will be found that the order in which lubricating oils are rated by transition is usually different from that in which they are rated by seizure and is more in agreement with actual service ratings:

Having completed the one-minute step test, the results are presented graphically by plotting:

(1) A curve of torque as a function of load (figures 1 and 4) to show relative frictional characteristics, and

(2) A curve of wear as a function of load (figures 2 and 5) to indicate the transition load.

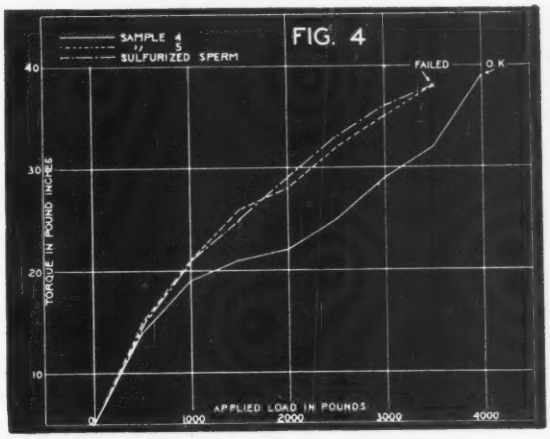
In the one-minute step test, preference is given to the term "transition load." The term "transition pressure" is reserved for the three-minute step test which is based upon the unit pressure exerted on the contact area by the applied load.

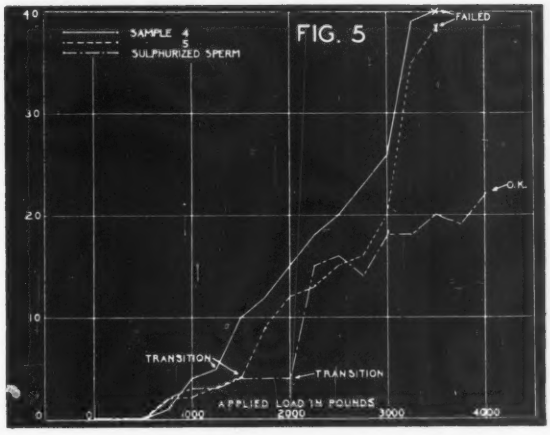
Three Minute Transition Pressure Step-up Test

This test is intended for the measurement of the ultimate film strength of a lubricant in terms of the unit pressure equivalent to its transition load. It is based upon the distribution of load over the area of contact, which area is visible and dimensional and results from a combination of wear and probable deformation of surfaces under relatively high test loads.

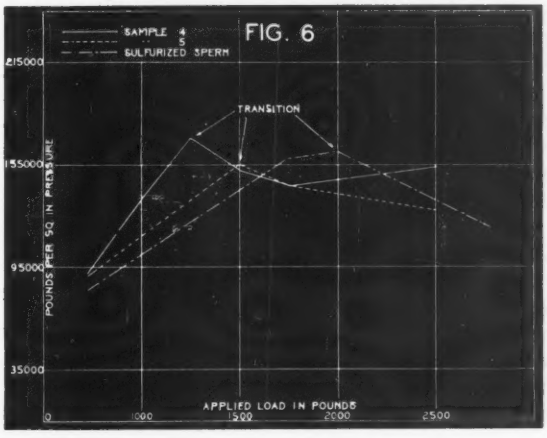
Under test conditions most of the wear is on the pin but, nevertheless, there is sufficient wear on the block faces to permit dimensional measurements to be made with an ocular micrometer and a 40-x magnification. It is only necessary to measure the width of the scar due to wear, as the length is the same in all cases, namely 0.48". The scar width is taken as the average of not less than thirty-two measurements; eight on each of the four scars of the two-block test assembly. It will be found that the scar width, and consequently the area, increases with the applied load. Therefore, at any point in the test, the ratio of the applied load to the scar area produced by that load is the resulting unit pressure, which, as psi pressure, is calculated from the equation of Plate III.

The three-minute step test is primarily for research studies and investigations up to the point of failure, or to machine capacity if the lubricant doesn't fail. It is carried out by placing a conditioned set of test pieces in the machine and, when the pre-determined starting temperature is reached, by applying a load of 500 lbs for a run-in period of three minutes. At the end of the run, the torque and wear are recorded and the test pieces are removed and cleaned. The scar width is then measured and recorded. When the machine has cooled to starting temperature, a new test assembly is





Vertical Axis Shows Wear (Teeth)



inserted in the machine and run in for three minutes at a load of 500 lbs and then the load is increased to 750 lbs and held there for three minutes. At the completion of the run, torque and wear are recorded, test pieces are removed and cleaned, and the scar width is measured and recorded. This procedure is repeated at load increments of 250 lbs, using a new test assembly and a 500 lb, three-minute run-in period to start each incremental run.

On completion of the tests, the psi pressure for each test load is computed and the results are presented graphically by plotting a curve of psi pressure as a function of applied load (figures 3 and 6) to show the transition pressure.

The outstanding feature of the curves of figures 3 and 6 is that, up to transition, the wear is linear and of such ratio to the applied load that the resultant psi pressure curve increases with the load. At the point of transition, however, the wear (scar area) increases with such magnitude that it is no longer linear and is out of all proportion to the applied load. This results in a reversal of direction with the psi pressure decreasing with increasing load, due to the excessive area over which the load is distributed.

After studying these curves in conjunction with the wear on the pin and block faces, it seems reasonable to assume that boundary film lubrication is maintained only to transition by polar orientation associated with some chemical reaction and that the wear is that which is normal to boundary friction and caused principally by the wearing down of asperities. Prior to transition the scars on the block faces are usually characterized by their freedom from scuffing which would indicate that there is no serious metal-to-metal contact. There is a strong possibility that, at the lower pressures, the lubrication is furnished by the full boundary film associated with substantial quantities of bulk oil. Under increasing test pressures, bulk oil is gradually forced out to a point where the boundary film sustains the load. Further increases in pressure may remove the horizontal double layers of the boundary film leaving the perpendicular monomolecular Langmuir layer as the sole lubricant on approaching transition.

At transition, this layer is evidently ruptured to the extent of its failure as a lubricant and then, by chemical reaction alone, is reestablished as a medium which permits metal movement to proceed without seizure or welding under increasing loads until it reaches its load carrying capacity or final breakdown. Beyond transition, the block scars are characterized by deep scuffing and occasional scoring which indicates that metal is virtually being torn away. Final breakdown probably results from the sudden welding of high spots by the excessive temperatures generated by the shearing and breaking off of minute metal particles augmented by heat liberated through intermolecular forces acting between opposing metal surfaces.

From the curves of figures 3 and 6, it appears that, under increasing pressure, an oil seems to function as a lubricant up to transition and as a metal cutting medium beyond transition. The curves also indicate that the region of boundary friction lies between the pressure at which dimensional wear first appears and the transition pressure. The range will not be the same for all oils. The transition pressure, therefore, is the ultimate film strength of a lubricant and can be defined as the first point in a psi pressure vs applied load curve at which the slope changes from positive to negative. It will be found that the transition pressure, as determined by the three-minute step test, is the psi pressure equivalent to the transition load as measured by the one-minute step test.

For all practical purposes it is not necessary to use all of the incremental loads recommended for the research procedure. The number of increments may be reduced to the minimum that will give the information sought. In many cases three points will suffice; e. g., one at transition and one each at the increments immediately preceding and immediately following transition. Augmenting these points with a test at a 750 lbs load and another at the second increment beyond transition gives a more complete picture of the curve over the entire range of boundary lubrication and well into the region beyond transition. It is always well to know what to expect beyond transition because a good boundary lubricant should be strong enough to sustain without seizure any momentary shock load that would force it into the post transition phase.

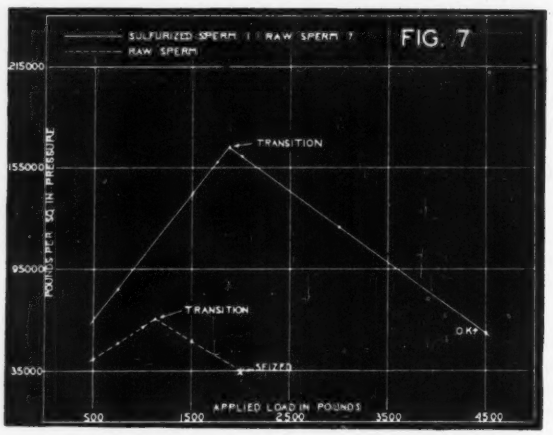


Figure 7 is presented to show the results of a complete research test on a lubricant that sustains the full 4500 lb load of the Falex machine. It will also serve to show the value of small amounts of additives in increasing the film strength of oils. The lower broken curve is that of raw sperm oil with a transition pressure of 65,000 psi. The upper solid curve is that in which the transition pressure has been raised to 167,000 psi by the addition of 1 part of sulfurized sperm oil, containing 12 per cent of sulfur, to 7 parts of raw sperm oil. It is to be seen that the addition of 1.5 per cent of sulfur raises the transition pressure of raw sperm oil 102,000 psi and imparts anti-welding properties by raising the seizure point from 2000 lbs to a point beyond the 4500 lb capacity of the machine.

. . The concluding part of this paper, covering practical applications of transition tests, will appear in the December, 1946, issue of *Lubrication Engineering.*

Protective Value of Industrial Lubricants*

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In this paper the author deals with the rust and corrosion preventing properties of oils used primarily as lubricants. Frequently the use of improperly compounded oils has failed to prevent rust under certain conditions, and in many cases this rust has not been properly identified but has been mistaken for wear, since the oxides formed act as abrasives when mixed or suspended in the lubricant.

The characteristics of lubricants compounded to overcome rusting are outlined, and steps to be taken in charging over to their use are indicated.

* * * * * * * * *

WHILE the chief function of a lubricating oil is lubrication, it must also act in several other capacities: as a coolant, a sealing agent, a scavenger, a transmitter of power and as a protector of the machinery in which it is being used, i. e., it should prevent rusting and wear caused by rusting.

The ability of lubricating oil to adhere tenaciously and thus to protect metal surfaces is probably its most important and at the same time its least understood property. In the following we aim to point out the significance of this property and its relationship to the various functions of a good lubricant. While there is a vague recognition of differences in performance of various oils in this respect, there does not exist a sufficiently descriptive and generally accepted term to name this phenomenon. Such expressions as oiliness, lubricity, wetting of or plating on metal surfaces are extremely difficult to define.

The following discussion is limited to the protective action of certain surface active industrial lubricants and does not concern itself with film type rust preventive oils which are not primarily intended to act in a lubricating capacity.

Lubricating oil can be regarded as being composed of an inert vehicle and of active ingredients which either occur naturally or are added. This inert vehicle represents the bulk of the oil and its main function is that of a coolant and a carrier of the active ingredients. As a lubricant it is useful only in fluid film lubrication where no metal to metal contact occurs; its surface activity[1,2] is negligible. Proper selection of the crude oil and of the refining processes are, however, highly important in determining the basic oxidation stability of an oil and its susceptibility[3] to anti-oxidants, either naturally occurring or added. The resistance to oxidation of a lubricant is important, since this helps to insure retention of initial properties including surface activity, during use.

Surface active compounds to be effective must have a water soluble (hydrophilic) portion in their molecule and also a water-insoluble (hydrophobic) portion. Furthermore these two portions must be properly balanced. The hydrophilic portion is attracted by water while the hydrophobic (hydrocarbon) portion is kept in the oil phase. Such compounds, particularly those containing oxygen (carboxyl or hydroxyl groups, etc.) will readily orient themselves at an oil water interface thus reducing the interfacial tension (I.F.T.)[4]. In this way even minute quantities of these compounds can be detected. Highly treated hydrocarbon oils such as medicinal white oil, etc., have I.F.T.'s in excess of 50 dynes /cm while for most uncompounded lubricants this value is between 30 and 40 when new and often as low as 10 when used. It is a matter of common knowledge that medicinal type white oils are poor lubricants. It has been shown[5,6] that mineral lubricating oils form compounds on oxidation which are hydrophilic and which exhibit strong affinity for metal surfaces, and that in the early stages of normal oxidative deterioration the lubricity of a refined oil may actually improve.

It might appear that the IFT could be used as a measure of the surface activity of lubricants. Unfortunately, however, this is not the case. There are many surface active compounds which are undesirable as lubricants since they depreciate oil performance in service.

The question may also be asked why surface active compounds which orient themselves at the oil-water interface, should necessarily do the same at the oil-metal interface. Without going into the theoretical details, it is known that even a freshly prepared metal surface is instantly covered by at least a mono-molecular layer of metal oxide. Experience has shown that metal oxides

* *Presented at the American Society of Lubrication Engineers Meeting Saturday, April 6, 1946, Chicago, Illinois.*

are more readily wetted by water than by oil, i. e., they are hydrophilic. For example, if we immerse a freshly polished steel specimen in white oil free of surface active constituents and then place a drop of pure distilled water on the specimen, the water displaces the oil and soon rusting sets in. We may argue, however, that water is heavier than oil and the displacement is due to a difference in gravity. But, when we repeat the above experiment now using the equipment of the ASTM turbine oil rusting test (D-665-44T) where a one-half inch diameter polished steel rod is suspended in oil and after stirring for 30 minutes (at 140F) 10% distilled water is added, the rod will soon be covered with water droplets and rusting will begin within a short time. In a similar way we may demonstrate that oils containing surface active constituents will prevent adherence of water to the steel specimen and either entirely prevent or considerably minimize rusting.

Again we may be tempted to accept the ASTM rusting test as a measure of surface activity for an oil. However, some of the most surface active oils will perform poorly in service (they may cause oil deterioration resulting in the formation of sludge, etc.) and even result in an increased rate of rusting. This type of rusting may be due either to hydrolysis or to oxidation of oil additives. Metallic or non-metallic soaps often used as rust preventives have a tendency to hydrolyze upon continued exposure to the action of moisture and their surface activity is lost. Certain oil-additives are also oxidation unstable and may thereby turn water soluble and/or procorrosive i. e., they promote rusting. Apparently mere surface activity does not assure protection of metal surfaces in service.

The accelerated oxidation-corrosion tester developed by Pope of Eastman Kodak Company[7] predicts the

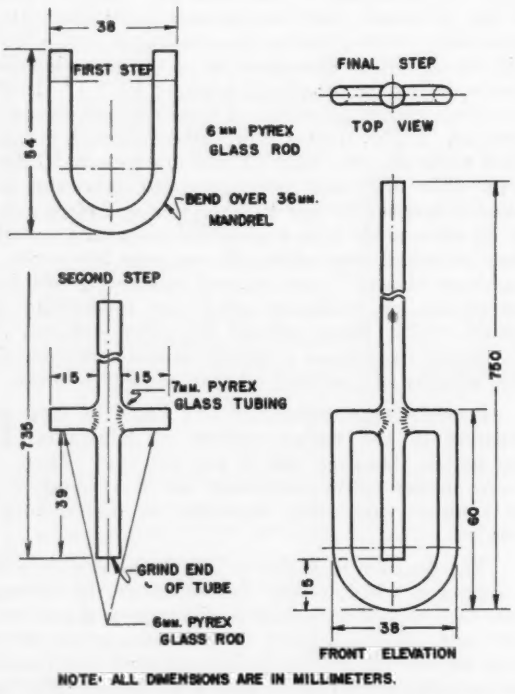

Figure 1. Oxygen Bubbler Tubes for TOS Test

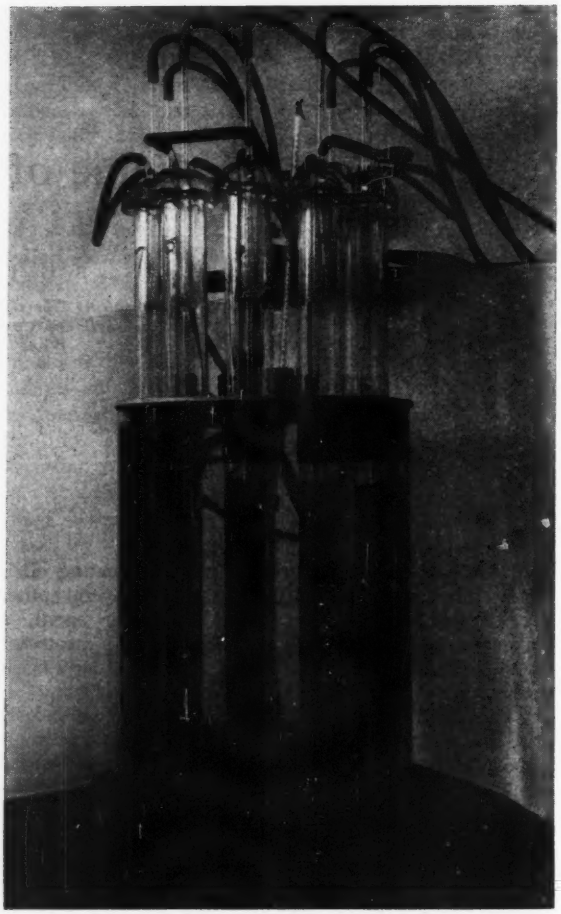

Figure 2. Turbine Oil Stability Test

useful life of a lubricating oil, determines an oil's ability to protect ferrous materials from rusting and establishes at what point during the life of an oil corrosion products are formed. By employing Mr. Pope's criteria of oil deterioration (rusting, sludging, etc.) similar results can also be obtained with the simpler Turbine Oil Stability Test[8, 9, 10]. The ASTM committee working on turbine oil oxidation (D2-CIII) has recently further simplified this test by replacing the fritted glass oxygen delivery tube with an open end bubbler (see Figure 1) and is now investigating substitution of service characteristics such as rusting, sludging, etc., for acid (neutralization)[11] value heretofore used for determining the useful life of a turbine oil (Figure 2).

The emphasis placed in recent years on the rust preventive action of turbine oils[12, 13] has opened up an entirely new field for the developmnt of industrial lubricants. Rusting of machinery under operating conditions has frequently not been recognized as such and was often mistaken for wear. In idle equipment rusting may occur even during a week-end shut down if the lubricant lacks surface activity and drains off or is displaced by condensation of water. When such equipment is again started up, the rust wears off. Typical cases are reduction gears and anti-friction bearings[14]. The red (ferric) or black (magnetic) iron oxides dispersed in the oil act as abrasives and greatly accelerate wear. Even the hydrophilic oxidation products of unin-

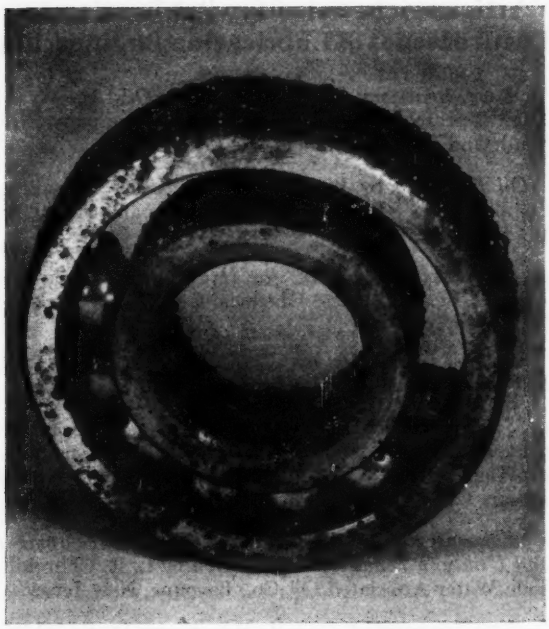

Figure 3. Corrosion Caused by Gasket Material and Water

hibited oil may be unable to prevent rusting (and wear). In fact, it has been shown by Dantsizen[15] of General Electric, that low molecular weight water soluble fatty acids (formic and acetic) which are some of the decomposition products of uninhibited lubricants, are rust promoters. There is strong evidence that the increased rate of wear often observed with internal combustion engines under low temperature operating conditions, is also due to rusting[16]. In this last case the water soluble acidic oxidation products of the fuel further aggravate the situation.

Examples of the consequences of faulty lubrication caused by lack of protective ability of the lubricants are shown in Figures 3 and 4.

The solution of the problem is to employ surface active lubricants which are able to wet metal surfaces forming a protective film and rendering these surfaces water repellent. Thus, rusting and consequent wear can be prevented and the machinery protected by proper selection of the lubricant. The replacement rate of ball bearings on standby pumps in solvent refining of petroleum lubricants was very high until a turbine oil type rust preventive oil was employed as lubricant.

Often modern methods of processing create abnormally severe rusting conditions. One such case was a large aircraft plant using a high speed machining technique. Here the metal working machinery showed an alarming rate of rusting which may have been aggravated by a highly humid atmosphere. It was necessary to overhaul some of the machine tools as frequently as every three months at which time parts rusted beyond repair had to be replaced. Some of the large machines took several days to dismantle and the cost in labor, replacement parts and lost operating time became prohibitive. Several hydraulic oils had previously been tried without success, including a fatty oil blend which sludged excessively. In this case a special non-sludging lubricant was developed which resisted rusting induced by high humidity. The oil was tested in the laboratory with the ASTM Turbine Oil rusting test procedure (D-665-44T) and was found to protect the steel specimens immersed in water under the prescribed test conditions (140F, 48 hours testing time) without permitting the formation of any rust.

Before introducing this new lubricant at the aircraft plant, all lubricating systems were first thoroughly cleaned. In those machines in which the oil could be heated, a rust preventive cleaning lubricant was first employed (at 150F) for a period of from two days to two weeks of operation. In these cases no shutdown was necessary and no operating time beyond that required for the oil change was lost. Then the cleaner was replaced by the rust preventive lubricant. In cases where heating was not possible the machines were cleaned manually, then reassembled and charged with the new lubricant. From that time on for a period of over a year no more trouble due to rusting has been reported. The oil in the machines cleaned with the lubricant cleaner continued to loosen accumulated rust and was changed bi-monthly until no more rust showed. The manually-cleaned machines showed no rust whatsoever. However, while in this case complete success was attained, it would be an error to conclude that this special lubricant will protect under all conditions of corrosion, irrespective of the type or concentration of corrosives involved. Another point worth remembering is that metal surfaces already wetted by water and attacked by rust will not be easily wetted by conventional bulk-type lubricants containing surface active agents and must first be cleaned and made accessible to the lubricating oil. Additives able to displace water and pre-formed rust from metal surfaces are usually too active to be used in industrial lubricants since they tend to decrease oil stability and cause sludging, etc.

In addition to rust prevention and to wear prevention directly or indirectly due to rusting, other equally tangible advantages can be realized by the use of these special lubricants. In certain hydraulic systems in several manufacturing plants, where straight mineral oils were unsuitable due to their lack of oiliness with resulting chattering and where fatty oil blends caused

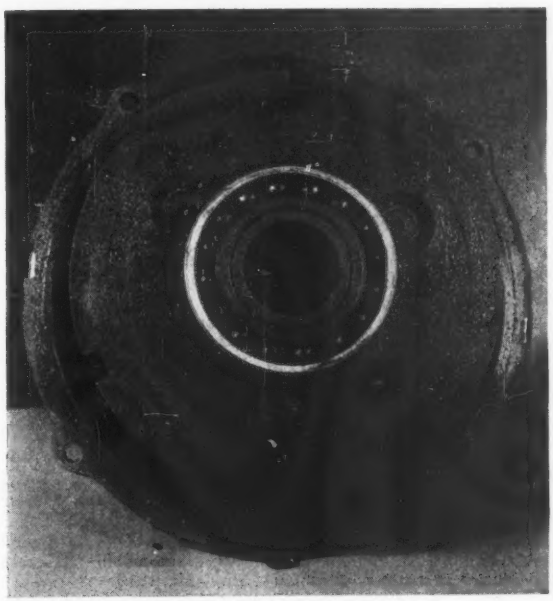

Figure 4. Condition of This Gear Box is Due to Improper Protection From the Oil

excessive sludging due to oil breakdown, a stable mineral oil blend containing surface active additives completely stopped chattering after only a short period of operation with this lubricant. In these cases the smooth operation was due to the superior wetting power imparted to the oil by these hydrophilic additives. The load bearing and torque characteristics of certain polar compounds which have been investigated recently by E. M. Kipp[17] are not the subject of this paper. When discussing protective surface active agents they should not be confused with extreme pressure (E.P.) additives, which prevent welding but otherwise have no protective value. On the contrary, they may actually promote rusting and thus contribute to wear. The basic difference between these two types of materials was pointed out by Larsen and Perry[18].

It should be kept in mind that the above discussed protective lubricants do not function as an easy cure-all and that considerable discretion is necessary when selecting surface active lubricants for special applications. Each case should be decided on its own merits and preferably through consultation between the oil user and supplier. The type and concentration of the oil additive should be such that it will accomplish the purpose without interfering with any other of the essential functions or service characteristics of the lubricant. Foremost to be kept in mind is the stability and freedom from sludging under the specific operating conditions. Thus the proper selection of the lubricant requires a high caliber of lubrication engineering.

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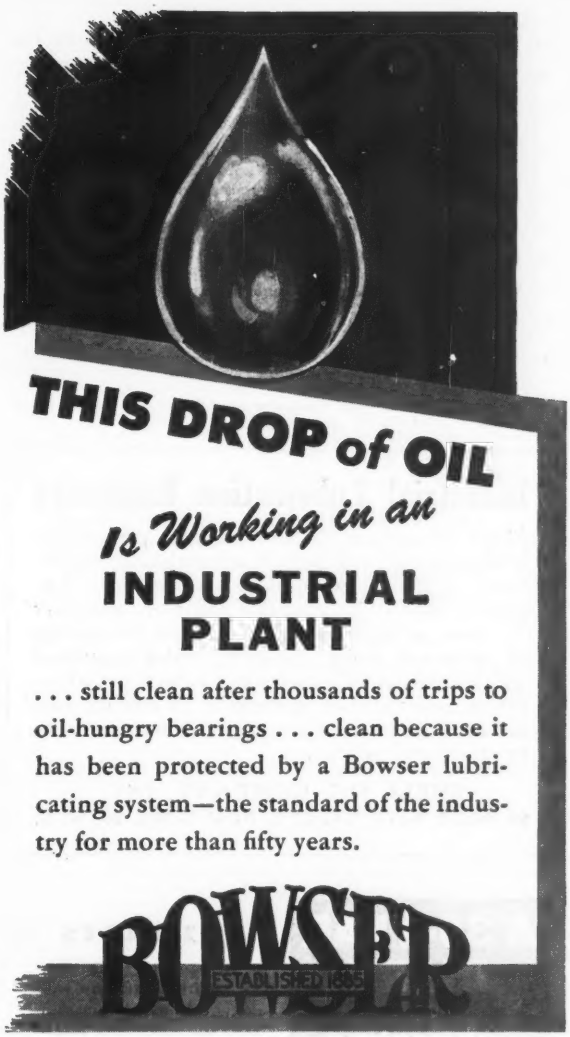
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OILS AND LUBRICANTS PATENT ABSTRACTS

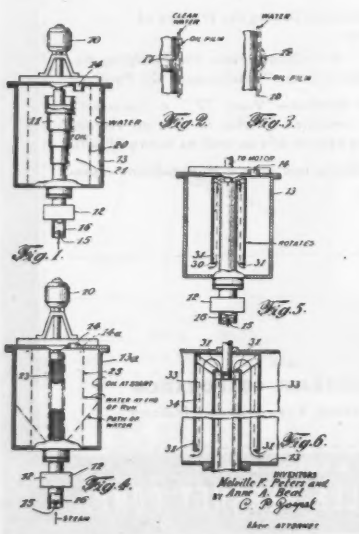
Conversion of Hydrocarbon Oils—Patent #2,398,773—Gerald C. Connolly, assignor to Standard Oil Development Co. A method of cracking hydrocarbon oil which comprises passing the oil in the absence of extraneous hydrogen through a cracking zone containing a catalyst comprising alumina as a major constituent and a boron compound as a minor constituent and wherein the alumina is treated with a salt containing boron and fluorine and maintaining said oil in contact with said cracking catalyst at cracking temperature for a period sufficient to obtain the desired cracking thereof.

Hydraulic Fluid and Lubricating Oil—Patent #2,398,943—Myron H. Kollen, assignor to Union Oil Co. of California. A composition of matter comprising a major proportion of a high boiling isoparaffin produced by reacting an olefin with a low boiling isoparaffin blended with a small quantity sufficient to change the viscosity index thereof substantially of a polymer of a low boiling olefin, said polymer having a molecular weight above about 10,000.

Lubricated Shaft Bearing—Patent #2,398,944—George E. Kopetz, assignor to Blaw-Knox Company. In an agitator bearing support for reaction kettles operating at non-atmospheric pressure, an agitator shaft, a sleeve member surrounding a portion of the agitator shaft intermediate the ends of said shaft, said sleeve member having an internal diameter throughout its length greater than the diameter of the agitator shaft so as to provide a continuous open space around the shaft from one end of the sleeve to the other for the circulation of lubricant therealong, said sleeve having a transverse external flange for securing it to a reaction kettle, axially spaced upper and lower bearings inside the sleeve, the said bearings being anti-friction bearings through which lubricant may flow, a cover member at each end of the sleeve forming a closure for the sleeve, there being a packing gland about the shaft in each cover member, a duct leading from a point above said flange to a point below the lower bearing and above the lower cover member, means at the other end of the sleeve between the upper bearing and the upper cover member providing a passage for the flow of lubricant, and means externally of the sleeve for circulating fluid under pressure into one end of the sleeve and out the other.

Lubricating Grease—Patent #2,399,063—Jacob M. Schantz, assignor to Hercules Powder Co. A lubricating grease comprising a mineral oil-soluble soap of a rosin having at least about 50% of the double bonds thereof saturated with hydrogen, in conjunction with a mineral oil, said soap being present in the amount of at least about 10.0% by weight of the finished grease.

Method for Reclaiming Crankcase Oil—Patent #2,399,140—Melville F. Peters and Anne A. Beal, assignors to Fred I. McCarthy. The process of reclaiming crankcase or similar oil compounds, which consists in subjecting the oil compounds as they leave the crankcase and mixed with a solvent to dissolve impurities in the compounds and neutralize the acids of the compounds, to a centrifugal force and to a stirring force, both against the action of gravity, then subjecting the oil and the solvent in respective parallel surface area sheets to contact actions, moving said parallel spread out sheets over each other at varying velocities in respect to each other, and subjecting said so moving parallel spread out sheets to the action of centrifugal forces for forcing the solvent through the sheet of oil, while moving the oil sheet in surface area contact over the solvent sheet, whereby the cleaned oil freed from the solvent is separated from the solvent.



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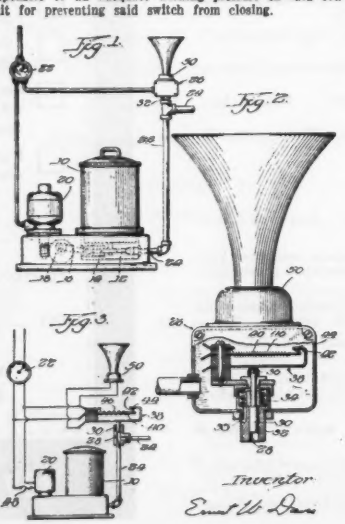
Lubricating Apparatus—Patent #2,399,171—Ernest W. Davis. In lubricating apparatus, means for intermittently completing an electric circuit at regularly recurring time intervals; an electric motor in said circuit; a lubricant pump driven by said electric motor; a discharge conduit for said lubricant pump; an electrically actuated alarm device; a bimetal switch for connecting said alarm device in said circuit in parallel with said motor when said bimetal is heated; an electric heater for heating said bimetal, said heater being connected in said circuit in parallel with said motor; and means responsive to an adequate working pressure in said conduit for preventing said switch from closing.



Lubricant Pump—Patent #2,399,172—Ernest W. Davis, assignor to Stewart-Warner Corp. In a three-stage lubricant pump having, a container for holding a main body of lubricant; a movable cylinder within said container; a piston for said cylinder, said piston being positioned within the space normally occupied by said main body of lubricant; means for producing reciprocating movement of said movable cylinder relative to said piston and relative to said main body of lubricant, said reciprocating movement extending between a position in which said movable cylinder is removed from said piston and a position in which said movable cylinder surrounds said piston, whereby movement of said movable cylinder through said main body of lubricant in a direction towards said piston, will first shave off a segregated quantity of said lubricant, and whereby continued movement of said movable cylinder to a position surrounding said piston, will then displace said segregated lubricant longitudinally within said movable cylinder; secondary pumping means connected to said movable cylinder for receiving and re-pumping the lubricant segregated and displaced thereby; and a booster pump for applying high pressure to said re-pumped lubricant, said booster pump being actuated by said reciprocating means, and said booster pump receiving lubricant from said secondary pumping means.

Dehydration of Transformer Oils—Patent #2,399,192—Peter P. Alexander, assignor to Metal Hydrides, Inc. In the method of dehydrating transformer oil containing a small amount of moisture, the improvement which comprises passing the transformer oil through a body of finely divided metal hydride to bring the moisture into intimate reactive contact therewith, permitting the hydrogen resulting from the reaction to escape as a gas from the transformer oil, and separating the dehydrated transformer oil from the solid resulting from the reaction.

Composition of Matter Suitable for Use as a Lubricant and Lubricant Comprising the Same—Patent #2,399,243—John M. Musselman, assignor to The Std. Oil Co. A composition of matter suitable for use as a lubricant and as an addition agent to improve the characteristics of lubricating oils and greases, comprising the reaction product of a phosphorus sulfide with a fatty acid ester of a mono-atomic alcohol, said ester having a boiling point above that of the reaction temperature and having not over 22 carbon atoms, reacted at a temperature at which oxygen in the ester is replaced by the sulphur of the sulfide and said replaced oxygen combined with the phosphorus of the sulfide, the amount of the sulfide being at least sufficient to substantially complete the reaction that occurs at said temperature.

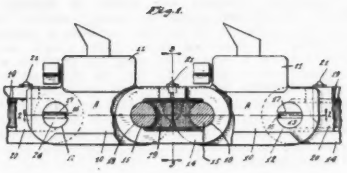
Steam Turbine Oils—Patent #2,399,510—Albert G. Rocchini, assignor to Gulf Research and Development Co. A method of preventing the corrosion of metal parts of steam turbines lubricated by a highly refined paraffinic oil containing a water-insoluble alkyl phenolic antioxidant in the presence of salt water comprising incorporating in said lubricating oil 0.005 to 0.5 per cent by weight of cyclohexylamine oleate.

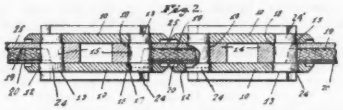
Drying Oils and Method for the Preparation Thereof—Patent #2,399,697—Fred J. Stark and George H. Slack, assignors to Fred J. Stark, George H. Slack, R. M. Rutledge, and Harry A. Hirst, as trustees. A method of producing a drying oil which comprises chlorinating a soy bean oil by the action of nascent chlorine and then subjecting the reaction product to the action of nascent oxygen.

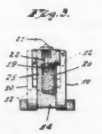
Mineral Oil—Patent #2,399,817—Ronald E. Meyer, assignor to Socony-Vacuum Oil Co., Inc. An improved mineral oil composition comprising a mineral oil fraction having in admixture therewith a minor proportion, sufficient to improve the viscosity characteristics of said oil fraction, of an oil-soluble, neutral co-polymer of a diolefin and a carbonyl compound selected from the group consisting of an unsaturated aliphatic ketone and a aliphatic aldehyde.

Catalytic Cracking of Hydrocarbon Oils—Patent #2,400,020—Jerry A. Pierce and Clellie T. Steele, assignors to Standard Oil Development Co. A process for cracking hydrocarbon oils which comprises passing the oil to be cracked in contact with an active catalyst comprising a bentonite clay activated by treatment with oxalic acid, the amount of said acid in pure state being at least 20% of the weight of the clay, and keeping the oil in contact with said catalyst while at cracking temperature for a period sufficient to obtain the desired cracking thereof.

Compounded Oil—Patent #2,400,106.—George H. Denison, Jr., and Paul C. Condit, assignors to California Research Corp. A composition of matter comprising a major proportion of an oil of lubricating viscosity and a small amount each, not less than about 0.1% by weight based on said oil, of a salt of a thiocarbamic acid and an aliphatic selenide selected from the group consisting of aliphatic monoselenides and aliphatic polyselemides.







Lubrication for Mining Machine Chairs—Patent #2,400,230—Frank L. Fulke, assignor to Frank Prox Co., Inc. A chain link comprising a main body formed, adjacent each of its opposite ends, with a transverse perforation, said perforations being located upon substantially parallel axes, and said body further being formed with a lubricant-receiving cavity, the extent of said cavity in each direction from the plane common to the axes of said perforations being at least equal to the radius of one of said perforations, throughout the region between said axes.

Method of Acid Treating a Viscous Hydrocarbon Oil—Patent #2,400,298—Benjamin G. Jones, Assoc., and Leslie H. Sharp, assignors to Tide Water Associated Oil Co. The method of acid treating oil which comprises: contacting a viscous hydrocarbon oil with concentrated sulphuric acid for a time and at a temperature sufficient to cause the acid to react with unstable constituents of the oil to form oil-soluble sulphonation products and oil-insoluble acid sludge, centrifuging the contacted oil to remove said sludge, maintaining the sludge free oil without further treatment for a period of time between ten minutes and about one hour sufficient to cause unstable oil-soluble constituents to polymerize and form oil-insoluble bodies, centrifuging said bodies from said oil, then contacting the oil with excess alkali to absorb contained acidic bodies and removing the contacted alkali from the oil.

Refining Hydrocarbon Oil—Patent #2,400,373—Henry G. Schutze, assignor to Standard Oil Development Co. A process of treating a hydrocarbon oil comprising toluene and olefins comprising the steps of acid treating said oil, subsequently neutralizing said acid treated oil with a concentrated aqueous solution of caustic alkali, separating the caustic solution therefrom, heating the oil to a temperature in the range of 300 to 325 F, admixing the hot oil with an aqueous solution of caustic alkali having a gravity in the range of 18 to 24 Bé, maintaining said oil in intimate contact with said hot solution for no less than ten minutes, subsequently separating said oil from said hot solution, vaporizing said oil at a temperature of no greater than 525 F and condensing a desired fraction.

Process for Breaking Petroleum Emulsions—Patent #2,400,394—Melvin De Groote and Bernhard Keiser, assignors to Petrolite Corp., Ltd. A process for breaking petroleum emulsions of the water-in-oil type, characterized by subjecting the emulsion to the action of a demulsifier.

Composition of Matter and Process for Preventing Water-in-Oil Type Emulsions Resulting from Acidization of Calcareous Oil-Bearing Strata—Patent #2,400,395.—Melvin De Groote and Bernhard Keiser, assignors to Petrolite Corp., Ltd. A process for preventing water-in-oil type emulsions resulting from acidization of calcareous, oil-bearing strata, which consists in introducing into the cognate fluids of a well, prior to emergence, a water-soluble member.

Catalytic Treatment of Hydrocarbon Oils—Patent #2,400,446—Preston L. Veltman, assignor, by mesne assignments, to The Texas Company. In thermal conversion reactions selected from the group consisting of catalytic cracking and reforming hydrocarbons to produce high octane gasoline hydrocarbons, the method which comprises bringing said first-mentioned hydrocarbons at conversion temperatures into brief, intimate contact with a solid catalyst substantially stable and non-volatile at elevated temperatures below about 1200 F, which is substantially free of sodium and potassium and comprises aluminum fluoride hemi-hydrate in association with an adsorbent material such that there is substantial conversion of feed hydrocarbons into said high octane gasoline hydrocarbons.

Art of Lubrication—Patent #2,400,492—Willard L. Finley and James H. Kirk, assignors to Sinclair Refining Co. The mixed calcium salts of alkyl phenol sulfides of which the alkyl groups contain from four to six carbon atoms and alkyl esters of salicylic acid of which the alkyl groups contain from six to eighteen carbon atoms.

Method of Purifying and Deodorizing Crude Oil—Patent #2,400,515—Floyd A. Kent and Clarence W. Patrick. A method of treating crude oil which consists in first heating the oil to approximately 110 F, then mixing a predetermined volume of hydrated lime and water so that it will readily flow, adding this mixture to the oil, adding a predetermined volume of chlorine acid to the mass, and then agitating the mass for a predetermined length of time.

Treatment of Tall Oil—Patent #2,400,607—Ernest Segessemann, assignor to National Oil Products Co. A process of treating tall oil to separate a fatty fraction therefrom which comprises esterifying the fatty acids in tall oil with a monohydric alcohol, hydrogenating the fatty acid esters in the esterified mixture, decreasing the temperature of the resulting mass in the presence of a solvent to effect precipitation of fatty acid esters and removing the precipitated fatty acid esters from the remaining solution.

Turbine Oil—Patent #2,400,611 — Herschel G. Smith and Troy L. Cantrell, and John G. Peters, assignors to Gulf Oil Corp. An improved, anti-rust turbine oil comprising a mineral lubricating oil and an amount sufficient to retard corrosion of metal of an oil-soluble composite improvement agent capable of imparting excellent anti-rust properties thereto, said composite improvement agent being a homogeneous blended mixture of a polyvalent metal salt of N-alkyl phthalamidic acid and amine addition salts of 3-methylbutyl, 2-ethylhexyl phosphoric acid with primary fatty amines and secondary cyclohexyl amines, respectively.

Steel Post Oiler Cup—Patent #2,400,798—Henry P. Witt. An oiling device for fence posts, comprising a cup-shaped body integrally formed on the upper end of the fence post and having a bottom and openings in the bottom adjacent the surface of the fence post, and waste material in the cup-shaped body to be saturated with oil.

Desalting Crude Oils—Patent #2,400,985—Bernard L. Evering and Arthur P. Lien, assignors to Std. Oil Company. The method of desalting a crude petroleum oil containing inorganic chlorides selected from the group consisting of alkali metal chlorides and alkaline earth chlorides comprising contacting said crude oil with liquid anhydrous hydrogen fluoride in an amount and for a time sufficient to convert said chlorides to fluorides with the formation of hydrogen chloride and removing said hydrogen chloride.

Desalting Crude Oil—Patent #2,400,986—Vanderveer Voorhees, assignor to Std. Oil Company. The method of removing water and inorganic salts from crude oil containing the same comprising contacting said crude oil with a hydrogen fluoride-water mixture containing not more than 50% HF, separating an oil phase comprising crude petroleum oil substantially free of water and inorganic salts, and an aqueous phase comprising hydrogen fluoride, water and inorganic fluorides.

Oil Burner—Patent #2,401,086—Harry C. Little. In an oil burner, a container having bottom and side and top walls, means for admitting oil to said container, means for admitting air to said container adjacent said top wall, said top wall having a discharge opening centrally thereof, means guiding said air along said top wall inwardly toward said discharge opening, said last means being provided with guide means to impart to air and oil vapor moving along the underside of the top wall towards the center of the container a downward component of movement so as to set up a circulation of toroidal convolutions of air and oil vapor within the container.

Mineral Oil Composition—Patent #2,401,273—Orland M. Reiff and Donald W. Andrus, assignors to Socony-Vacuum Oil Co. An improved mineral oil composition comprising a viscous mineral oil and in admixture therewith a minor proportion, from about 0.1 per cent to about 5 per cent, of an oil-soluble metal hydrosulfide of a basic polyvalent-metal salt of an alkyl-substituted aromatic hydrocarbon compound, said alkyl substituent being an oil-solubilizing alkyl group.

Treatment of Oils and Waxes—Patent #2,401,339—Russell P. Dunmire, assignor, by mesne assignments, to Buckeye Laboratories Corp. The process for removing impurities from a used fatty substance of the class consisting of animal oils and waxes, which process comprises mechanically mixing and agitating the fatty substance and a solid adsorbent material in a sealed container to adsorb the high boiling point impurities, heating the mixture of the fatty substance and the solid adsorbent material in the sealed container under vacuum at a temperature substantially in the range of the incipient azeotropic distillation point of the constituents of the fatty substance being treated to distill off the low boiling point volatile impurities, and separating the adsorbent material with its adsorbed impurities from the fatty substance being treated to recover the latter.

Process for Treating Rolling Oils—Patent #2,401,340—Russell P. Dunmire and James A. Camelford, assignors, by mesne assignments, to Buckeye Laboratories Corp. In the operation of rolling mills where a supply of water and a quantity of fatty oil are caused to flow over and about the material being treated in the mill and producing a contaminated water and oil sludge, the process of recovering and purifying the oil for recurrent use in the mill comprising the steps of collecting the water and the oil sludge from the mill, separating the oil sludge from the water, re-refining the separated oil sludge by mechanically mixing and agitating the separated oil sludge with a solid adsorbent material in a sealed container to adsorb the high boiling point impurities, heating the mixture of the oil sludge being treated and the solid adsorbent material in the sealed container under vacuum to distill off the water and the low boiling point volatile impurities, and separating the adsorbent material and the impurities from the oil being treated by filtration to recover the latter for further use.

Treatment of Compounded Oils—Patent #2,401,341—Russell P. Dunmire, assignor, by mesne assignments, to Buckeye Laboratories Corp. The process for removing impurities from a contaminated compounded oil of the class consisting of mineral oils compounded with an oil-soluble additive substance, which process comprises treating the compounded oil without materially affecting any of the constituents thereof by mechanically mixing and agitating the contaminated compounded oil and a solid adsorbent material in a sealed container to adsorb the high boiling point impurities, heating the mixture of the compounded oil and the solid adsorbent material in the sealed container under vacuum at a temperature in a range which extends up to substantially 100 F beyond the incipient azeotropic distillation point of the constituents of the compounded oil being treated to distill off the low boiling point volatile impurities, and separating the adsorbent material with its adsorbed impurities from the compounded oil being treated to recover the latter.

Treatment of Castor Oil, and in Castor Oil Containing Products—Patent #2,401,369—Adam J. Paluszek, assignor of 15 per cent to James H. Hayes. In the treatment of castor oil, the steps of distillating castor oil in the presence of a lesser amount of distillation agent from the class consisting of clay, diatomaceous earth, aluminum hydrate, anhydrous silica, and silica gel, until substantially all of the oil has undergone distillation but without solidification of the distilland, and condensing the distillate vapors.

Production of Oil Solutions of Alkaline Earth Metal Sulphonates—Patent #2,401,614—Vladimir L. Cheehot and Llewellyn S. Howe, assignors to The Atlantic Refining Company. The method of removing solid materials from an oil solution of an alkaline earth metal sulphonate having relatively poor filtering characteristics, which comprises mixing with said solution an organic solvent from the group consisting of aliphatic alcohols, glycols, and glycol ethersin a small but sufficient amount to lower the viscosity of said solution, and filtering said solution through a filtering medium capable of retaining said solid materials.

Synthetic Drying Oils—Patent #2,401,769—Charles J. Mighton, assignor to E. I. duPont de Nemours & Co. A synthetic drying oil comprising a homogeneous composition which is composed of a copolymer of a furylethylene and a fatty oil of the group consisting of drying and semi-drying oils, said oil and furylethylene being present in said copolymer in amount by weight of from about 65% of the fatty oil and 35% of furylethylene to 95% of the fatty oil and 5% of furylethylene.

Polymerization of Olefins to Oily Polymers—Patent #2,401,933—Arthur B. Hersberger, assignor to The Atlantic Refining Co. The method of producing lubricating oil, which comprises providing a mixture of liquid propylene and liquid isobutylene, the propylene representing 40% to 60% of the mixture, bringing the temperature of the mixture within the range of —10 C to +35 C and spraying the mixture with a solution of a Friedel-Crafts type catalyst in a lower alkyl halide, said catalyst solution being applied in the form of finely divided liquid particles at temperature between —10 C and +35 C and the mixture being vigorously agitated during the addition of the catalyst solution and the ensuing polymerization reaction.

Stabilization of Petroleum Hydrocarbons—Patent #2,401,957—Chas. J. Pedersen and Richard O. Bender, assignors to E. I. duPont de Nemours & Co. Petroleum hydrocarbons, boiling below 760 F and normally subject to deterioration on storage having incorporated therein, in a small proportion sufficient to inhibit such deterioration, a 2-aminomethyl-4-aminophenol in which 1 to 2 amino hydrogens of the aminomethyl group are substituted by alkyl groups and 0 to 2 amino hydrogens of the 4-amino group are substituted by alkyl groups.

Process and Agent for Breaking Petroleum Emulsions—Patent #2,401,966—Richard A. Salathiel, assignor to Standard Oil Development Co. A method for resolving a water-in-oil emulsion which comprises adding to it a substance obtained by reacting a fatty material selected from the group consisting of fatty oils and fatty acids with a polyalkylene glycol containing at least 8 carbon atoms, the fatty material being present in said substance in a thickened form induced by a treatment selected from the group consisting of oxidation and polymerization.

Corrosion Resistant Composition—Patent #2,401,993—Jones I. Wasson and Gordon W. Duncan, assignors to Standard Oil Development Co. A method of lubricating

steel bearings under corrosion inhibited conditions in the presence of substantial amounts of water, which comprises employing in the lubrication of said bearings a mineral lubricating oil containing a tertiary butyl ether of ortho tertiary butyl paracresol and about 0.01 to about 0.5% of "lorol" amine salicylate in an amount sufficient to exert a corrosion inhibitory effect.

Manufacture of Lubricating Oils—Patent #2,402,288—Arthur Lazar and John C. Carter, assignors to Tide Water Association Oil Company. A method of preparing a lubricating oil having reduced tendency toward oxidation, ring-sticking, and corrosion which comprises: removing napthenic acids and other acidic substances from a naphthene base oil whose principal constituents having boiling points above 375 F at 2 mm. Hg. absolute pressure, treating the purified oil with a sulphonating agent to provide sulphonic acids dissolved in the oil, removing the spent sulphonating agent, converting the sulphonic acids to polyvalent metal sulphonate free of alkali metal sulphonate and incorporating the same in a hydrocarbon lubricating oil in oxidation inhibiting amount.

Oil Solutions of Basic Alkaline Earth Metal Sulphonates and Method of Making Same—Patent #2,402,325—William K. Griesinger and Edmond H. Engelking, assignors to The Atlantic Refining Company. The method of producing a hydrocarbon oil solution of a basic alkaline earth metal sulphonate, which comprises intimately contacting hydrocarbon oil with a sulphonating agent, separating the oil containing oil-soluble sulphonic acids from the spent sulphonating agent, and reacting the oil solution of sulphonic acids at 220 F to 230 F, in the presence of steam, with 80% to 120% of a basic alkaline earth metal compound in excess of that required to form a neutral sulphonate.

Treatment of Oil Wells—Patent #2,402,433—John E. Munn, assignor to Chemical Service Co. The method of treating oil wells in which water is present which comprises forcing a liquid capable of reducing the surface tension of water into the oil-producing stratum below the bottom of the well, thereafter introducing a second liquid consisting essentially of carbon tetrachloride into the same portion of the stratum to displace the water which has been treated with the first liquid, and thereafter sealing the bottom of the well only below a given oil producing level against the upflow of liquid therethrough.

Lubrication Control—Patent #2,402,467—Albert S. Thompson, assignor to Westinghouse Electric Corp. In a gas turbine provided with one or more bearings, a pump driven by the turbine for supplying lubricating oil to the bearings, suction means for draining oil from the bearings, and means for operating the suction means a desired time interval after shutting down the turbine.

Foam Inhibited Oil—Patent 2,402,487—Augustus H. Batchelder and Fitzhugh S. Rollins, assignors, by mesne assignments, to California Research Corp. A method of producing foam inhibited lubricants, comprising incorporating a short chain nitro aliphatic alcohol containing at least one hydroxyl group for each four carbon atoms into a mineral oil of lubricating viscosity to produce a concentrated dispersion of the said alcohol in mineral oil, and blending the said concentrated dispersion in mineral lubricating oil to produce a lubricating oil containing a small amount, sufficient to inhibit foaming of the oil, of said alcohol.

Viscous Mineral Oil Compositions—Patent #2,402,792—Roger W. Watson and James W. Gaynor, assignors to Standard Oil Co. A stable viscous substantially wax-free hydrocarbon oil comprising a hydrocarbon oil normally susceptible to oxidative deterioration and a phenylene diamine having the general formula

in which R is an acyl radical and R is a substituent selected from the class consisting of hydrogen, aliphatic, cyclo-aliphatic, aralkyl, and acyl radicals, said phenylene diamine being used in small but sufficient quantities to inhibit the oxidative deterioration of said oil.

Treatment of Hydrocarbon Oils—Patent #2,402,804—Vladimir L. Chechot, assignor to The Atlantic Refining Co. The method of refining hydrocarbon oil, which comprises contacting the oil with a finely divided decolorizing metal silicate absorbent at a temperature between 230 F and 260 F, and thereafter contacting the oil with an additional quantity of said finely divided absorbent at a temperature between 180 F and 220 F.

Method for Purifying Mineral Oils—Patent #2,402,844—Claudius H. M. Roberts, assignor to Petrolite Corp., Ltd. A non-dehydration process for removing water-dispersible impurities from an impure mineral oil containing not more than a few per cent of water, said oil containing small dispersed brine droplets with which are associated at least a portion of the impurities to be removed and said oil containing emulsifying agents, which process includes the steps of; mixing with said oil more than an equal volume of relatively fresh water while employing sufficient relatively fresh water to form a water-continuous dispersion and while employing a mixing action of such character and a sufficient quantity of said relatively fresh water to substantially suppress the formation of water-in-oil emulsions and disperse said oil in the form of relatively fine droplets throughout the water to present a large interfacial area across which transfer of impurities can occur, said mixing being of such character as to produce a dispersion which will separate readily and substantially spontaneously into bodies of oil and water unless maintained by agitation; delivering said water-continuous dispersion to a separating zone; and separating said dispersion gravitationally in said separating zone to form a body of water now containing water-dispersible impurities from the oil and a body of oil containing an amount of water which is not less than the water content of said impure oil.

Journal Lubricator—Patent #2,402,953—William J. Fitzsimmons. A bearing and lubricating assembly for the journal of an axle in a railway vehicle journal box, comprising a bearing element for mounting in the upper side of the box for bearing engagement with the journal, a lubricating roller supporting carriage below the journal having hook ends, rods engaging in said hook ends, suspension links extending downwardly from said bearing element at opposite sides of the journal and connected at their lower ends with said rods, said links including tension springs functioning to hold said carriage for pressure engagement of the rollers with the journal for feeding of lubricant from the bottom of the journal box to the journal.

Lubricating Composition—Patent #2,402,969—Rush F. McCleary, assignor to The Texas Company. A lubricating composition comprising a major amount of a hydrocarbon oil and a minor proportion, sufficient to impart detergent properties to said oil, of an oil-miscible compound of the class consisting of an aliphatic-ether-alcohol and an aliphatic-ether-metal alcoholate derivative of the phenolic compositions present in or derived from the oils extracted from the Anacardium genus of the Anacardiaceae family.

Lubricating Device—Patent #2,403,058—Ernest W. Davis. In a lubricating device, a plurality of vertically movable weights; means for alternately raising and releasing said weights to produce vertical reciprocating movement thereof; a plurality of pumps, each said pump being actuated by said motion of one of said weights; means for supplying lubricant to said pumps; a resilient stop for each said weight to limit the downward movement thereof; each said stop being stressed to exert a force in an upward direction; and adjustable means for overcoming said force in each said stop, and for selectivity positioning each said stop to provide a predetermined lowermost position for its corresponding weight, all of said stops being integral with each other.

Anticorrosion Composition—Patent #2,403,067—Paul W. Fischer and Vance N. Jenkins, assignors to Union Oil Co. of Calif. A non-aqueous anti-corrosion composition comprising mineral oil in which is dissolved in the order of 0.001% to 2.0% of a material containing an oil-soluble alkanol amide of an unsaturated non-hydroxy fatty acid, the alkanol constituent containing at least four carbon atoms and the fatty acid constituent containing at least ten carbon atoms.

Methods of Treating Oils—Patent #2,403,088—Kenneth Malcolm Laing, assignor to Aluminum Company of America. The method of treating oils which comprises contacting the oil with an adsorbent composed of alumina and fuller's earth proportioned in ratio of not less than about 1 and not more than about 10 parts of alumina to 1 part of fuller's earth, said alumina being an adsorptive product prepared by heating within the range of 250 to 800 C, a substance selected from the group consisting of aluminum hydrates and alumina in gelatinous form containing free or loosely held water.

Lithium Greases—Patent #2,403,104—Elvin B. Lien, assignor to Union Oil Co. of California. A lubricating grease comprising mineral oil, a minor proportion of of lithium soap, and a minor proportion of unsaponifiable oil obtained from the recovery of synthetic acids produced by the oxidation of lubricating oil fractions.

Lubricant—Patent #2,403,167—Herman E. Ballard. A sealing and lubricating composition comprising finely divided particles of synthetic rubber material of the class consisting of butadiene polymer and copolymer, chloroprene polymer, organic polysulphide, and plasticized vinyl chloride polymer distributed in discrete and undissolved form throughout a mixture of petrolatum and aluminum stearate.

Lubricant—Patent #2,403,234—John A. Patterson, assignor to The Texas Company. A lubricant comprising a mineral lubricating oil and 0.01—5% by weight of an oil-soluble sulfurized derivative of cardanol.

Method of Lubrication as Applied to the Processing of Aluminum and Aluminum Alloys.—Patent #2,403,238—Fred E. Rosenstiehl, assignor to The Texas Company. A method of lubrication as applied to the processing of aluminum and aluminum alloys in which the metal is subjected to a rolling operation, followed by annealing, which comprises supplying to the rolls and metal surfaces a hydrocarbon lubricating oil within the viscosity range of 35-100 Saybolt Universal seconds at 100 F, having incorporated therein a combination of 0.01—1.0% by weight of an oxidation product obtained by the partial oxidation of high molecular weight petroleum hydrocarbons, and 0.1—1.5% by weight of an N-substituted aromatic amine of the class consisting of phenyl naphthylamines, diaryl amines, and diamino diaryl alkanes possessing oxidation inhibiting properties.

Phosphatidic Lubricant and Method of Making—Patent #2,403,284—Joseph J. Jacobs, assignor to American Lecithin Co. A lubricant comprising a mineral lubricating oil containing between about .02% and about 15% of a composition having the properties of inhibiting the oxidation of, and the formation of naphtha insoluble in, said oil and consisting of a vegetable phosphatide and from 10% to 90% of a mineral oil, said mixture having been heated at a temperature of from about 200 F to about 375 F for between 1 hour and 24 hours before being added to said lubricating oil.

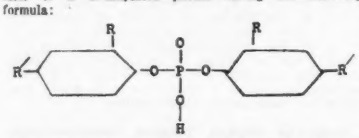
Lubrication System—Patent #2,403,397—Dan R. Rankin, assignor to Food Machinery Corp. In a lubricating system for supplying lubricant to a lubricant chamber, the combination of: means forming a cylinder having an air-tight closed end, the open end of said cylinder being adapted to communicate with said chamber; a cup plunger disposed in said cylinder and adapted when lubricated to make an airtight fit therewith; and an expansion spring in said cylinder between the closed end thereof and said plunger, said spring having sufficient expansive strength when compressed to expand and force said plunger toward the open end of said cylinder against the pressure of the atmosphere.

Mineral Oil Composition—Patent #2,403,453—Ferdinand Philip Otto, assignor to Socony-Vacuum Oil Co., Inc. An improved mineral oil composition comprising a mineral oil and to admixture therewith a minor proportion, sufficient to stabilize said oil against the deleterious effects of oxidation, of the reaction product obtained by the reaction of substantially one equivalent of a mono-hydroxy-aromatic compound, two equivalents of an aldehyde having more than one carbon atom and one equivalent of ammonia.

Solvent Extraction of Drying Oils—Patent #2,403,458—Olive Sue Ransom and Milton Zucker, assignors to Interchemical Corp. Method for treating heat bodied polymerized vegetable and marine drying oils to obtain oil fractions therefrom of increased drying properties which comprises, mixing such oil with a substantially anhydrous organic solvent consisting essentially of about 3 to 5 volumes of ethanol to 1 volume of ethyl acetate, permitting the mixture of solvent and oil to separate into two layers, each layer containing an oily constituent, separating the two layers and removing the contained solvent from the layer containing a predominance of the polymerized constituents having increased drying properties.

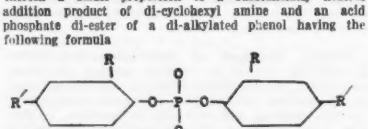
Additive for Lubricants—Patent #2,403,474—John D. Bartleson and Franklin Veatch, assignors to The Standard Oil Co. An additive for lubricants to improve their characteristics, comprising a metal derivative of a reaction product of a sulfide of phosphorus and an organic amine.

Mineral Oil Composition—Patent #2,403,764—Herschel G. Smith and Troy L. Cantrell, assignors to Gulf Oil Corp. An improved oil composition, effective as a lubricant for metal surfaces and capable of preventing corrosion thereof in the presence of moisture and air, comprising a petroleum lubricant containing in solution therein a small proportion of a substantially neutral addition product of a primary fatty amine containing from 8 to 18 carbon atoms and an acid phosphate diester of a di-alkylated phenol having the following formula:



wherein R represents a branched chain alkyl group and R' represents an alkyl group, said substantially neutral addition products having a pH between 5.5 and 7.5 and the proportion thereof dissolved in the lubricant being sufficient to prevent rusting of ferrous metals.

Mineral Oil Composition—Patent #2,403,765—Herschel G. Smith and Troy L. Cantrell, assignors to Gulf Oil Corp. An improved oil composition, effective as a lubricant for metal surfaces and capable of preventing corrosion thereof in the presence of moisture and air, comprising a petroleum lubricant containing in solution therein a small proportion of a substantially neutral addition product of di-cyclohexyl amine and an acid phosphate di-ester of a di-alkylated phenol having the following formula



wherein R represents a branched chain alkyl group and R' represents an alkyl group, said substantially neutral addition product having a pH between 5.5 and 7.5 and the proportion thereof dissolved in the lubricant being sufficient to prevent rusting of ferrous metals.

Additives for Lubricants—Patent #2,403,894—John D. Bartleson, assignor to The Standard Oil Co. A lubricant comprising an oil dispersible reaction product of an organic amine and a phosphorous sulfide subjected to a temperature of above 400 F and below temperatures at which the reaction product would be decomposed.

REVIEWS OF CURRENT BOOKS

ENCYCLOPEDIA OF HYDROCARBON COMPOUNDS. C_1-C_5.
By Dr. Joseph E. Faraday,

Chemical Publishing Company, Inc., Brooklyn, New York—1946. Loose-leaf Binder and Sheets. Price $15.00.

This is the first volume of a vast British undertaking which, it is hoped, will culminate in the creation of a complete Encyclopedia of Carbon Compounds. The initial step is a sorted collection of information on the compounds, composed of carbon and hydrogen alone, containing one to five carbon atoms.

The information presented for each compound is its name, molecular and structural formulas, occurence, outstanding physical properties and reactions, and every known method of preparation with complete bibliography for each. Over three hundred scientific journals are referred to in the compilation. The information presented is complete up to January 1944, and will be kept up-to-date by annual supplements to be furnished for insertion into the binder. A logical system of arrangement, modeled after that of Richter's Lexicon, is used to reduce the effort required to locate the desired information and for proper addition of supplementary sheets.

Faraday's Encyclopedia should greatly simplify the labors of a library researcher in the field of hydrocarbons. Each page is the equivalent of many hours spent poring over the chemical abstract journals.

ENGLISH-FRENCH AND FRENCH-ENGLISH TECHNICAL DICTIONARY—
By Francis Cusset,

Chemical Publishing Company, Inc., Brooklyn, New York — 1946. 590 pages. Price 5.00.

This new dictionary should be of real help not only to translators, librarians and students, but also to engineers. The many new words in both languages developed just prior to and during the War make it necessary to bring out dictionaries at frequent intervals, and the appearance of this dictionary is indeed timely.

The type is easy to read and the definitions are concise and to the point. The word listings are printed in a clear bold-face type with the definitions in conventional type, which aids in increasing the speed of reading.

The book is reasonably small in size and convenient to use.—*B. H. Jennings.*

A new booklet just published, discusses the physical and chemical properties of ten commercially important ketones produced by Carbide and Carbon Chemicals Corporation, 30 East 42nd Street, New York 17, N. Y. Specification and shipping data are given in this booklet, as well as information regarding principal uses for these products. Ketones are important intermediates in the synthesis of industrial chemicals, and possess a high solvency for nitrocellulose and "Vinylite" resins. They are also widely used in the extraction of drugs, stripping of dyestuffs from textiles, coagulation of rubber latex, and dewaxing of lubricating oils.

A copy of this booklet may be obtained from Carbide and Carbon Chemicals Corporation. Ask for Form 4767.

Also available from this same manufacturer is a new 12-page booklet "Physical Properties of Synthetic Organic Chemicals," designed as a condensed guide for research chemists, laboratory technicians and purchasing agents. Data on the physical properties, and applications for more than 175 synthetic organic chemicals are presented in tabular form.

Available without charge. Ask for "Form 6136."

The National Lubricating Grease Institute has just issued a new Technical Bulletin entitled: *"Determination of the Flow Characteristics of Lubricating Greases."*

This Technical Bulletin covers in detail the development of a Pressure-Viscosimeter suited for determining the apparent viscosities of lubricating greases over a considerable range of rates of shear.

The viscosimeter instrument and its method of operation are described and additional chapters in the Bulletin deal with the significance and application of grease viscosity data.

The Pressure-Viscosimeter, although developed primarily for determination of the flow characteristics of lubricating greases, is also suited for viscosity measurement of extremely viscous oils or for measurements at very low temperatures, wherein other types of viscosimeter instruments are not satisfactory. Chapters in the Bulletin give further information on this application.

Copies of the N.L.G.I. Bulletin on Determination of the Flow Characteristics of Lubricating Greases may be procured from C. E. Bolte, Sec'y, National Lubricating Grease Institute, 1116 Land Bank Bldg., Kansas City, Mo., at $1.00 each.

Chicago—Ray Shaw, president of The Chek-Chart Corporation, has just announced the appointment of Christy C. Butterworth as Managing Editor. A graduate of the U. S. Naval Academy at Annapolis, Butterworth has had a wide practical experience in industrial and automotive lubrication.

Before joining the Chek-Chart staff, Butterworth was associated with Business Collaborators, Inc., in St. Louis, publishers of technical literature in the lubrication field. He had been previously connected with the Curtiss-Wright organization, where he assisted in setting up lubrication schedules for aircraft production machinery as well as assisting in the supervision of mechanical construction of plant facilities.

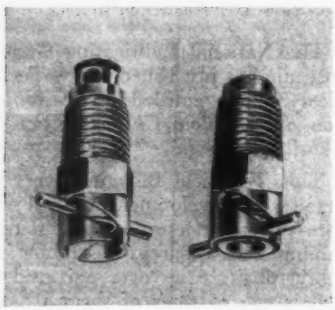
Mr. Butterworth is a member of the Society of Automotive Engineers, and was Vice-Chairman of the St. Louis Section of that body.

The appointment of Lew J. Franek as Production Manager has also been announced.

Mr. Franek brings to the Chek-Chart organization a wide practical experience in the printing and graphic arts field. During the five years preceding his connection with Chek-Chart, Franek had been a consultant to several score printing and publishing houses, assisting them in production and administrative reorganizations.

Mr. Franek is a member of the Milwaukee-Racine Past Presidents' Club of Printing House Craftsmen.

Drain Valve



To facilitate the draining of fuel, oil and other liquids, Curtis Automotive Devices, Inc., of Dayton, Ohio, have place on the market the "Curtis Superior *Drain Valve.*" Only one-quarter turn completely opens it . . . one easy tool-less operation. Simple construction coupled with quick action is said to make the Curtis Superior Drain Valve a "natural" where there is a drain problem. Curtis Superior Drain Valves are manufactured for radiators, blocks, heaters and other applications, in ⅛, ¼, ⅜ and ½ inch sizes.

BRIDGE
Specialties HEAVY CHEMICALS
CHEMICAL CO. INC.
Distributors of
FATTY ACIDS
GLYCERIDES
GLYCERINE
CHLOR. PARAFFINS
SULPHUR
TALL OIL
SOLUBLE OIL BASES
SULPHONATED OILS
GRAPHITE
DEGRAS
WOOL GREASE
LANOLIN
600 NORTH WELLS STREET
TELEPHONE MICHIGAN 3155
CHICAGO 10, ILLINOIS

Brooks Anniversary Bulletin Announces New Lubricant

"I. P." Leadolene, a modern (Indestructible pH-ilm) lubricant developed to meet the requirements of new production methods which use increased speeds, greater pressures, and high heat conditions, is described in a new bulletin published by the Brooks Oil Company of Cleveland, Pittsburgh and Hamilton, Ontario.

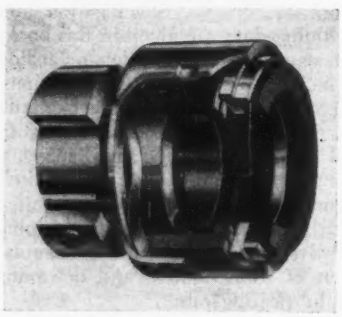
"I. P." Leadolene high film strength is claimed to be one of the products' many outstanding qualities. The high degree of adhesiveness possessed by "I. P." Leadolene is said to enable it to adhere to metal surfaces, thoroughly wetting them and preventing creepage and wiping action under extremely high pressures. Increased use of water in rolling mill operations requires a lubricant which is water repellent. "I.P." Leadolene successfully repels water, is not easily emulsified, and retains its stability in service and in storage, according to the manufacturer. "I. P." Leadolene lubricates successfully at low temperatures as well as high, and will not fail when temperatures unexpectedly change.

Another important feature of "I. P." Leadolene in industry is that every application is individually developed and approved and is constantly laboratory tested during its use by the customer.

This lubricant is said to be a neutral compound which will not change to an acid or alkali under any conditions, will not attack metal and, at the same time, will protect against corrosion by air, water, and many kinds of fumes.

Brooks Oil Company's anniversary bulletin describes in detail the unusual properties of "I. P." Leadolene and features ten outstanding examples of the new "I. P." lubricant's success in actual industrial use. The new Brooks Bulletin is carefully illustrated and designed to give the facts about "I. P." Leadolene with the greatest possible readability. For a copy write this publication or direct to the Brooks Oil Co., 315 E. Carson St., Pittsburgh 19, Pa.

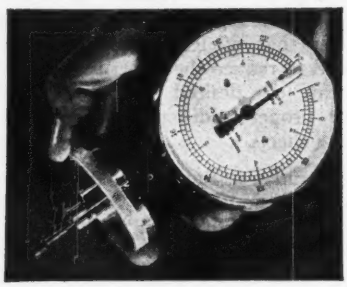
Mechanical Seal



A unique *seal for rotating shafts* has just been announced by Sealol Corporation of 45 Willard Ave., Providence 5, R. I. This new "Sealol CB" seal is designed for original equipment or replacement and is said to make stuffing boxes obsolete: it is designed to seal leaking shafts simply, permanently and economically and to exclude all foreign material.

The "Sealol CB" is packaged as a complete seal, without any loose parts. No skill or special tools are required to install the unit . . . it slides easily into position on the shaft and is locked in place with two setscrews. The only relative movement is at lapped faces and reasonable shaft run-out does not affect the performance of the seal. Available in non-corrosive construction for shaft sizes ½" to 1", other sizes to order. Descriptive circular upon request.

Tachometers



Herman H. Sticht Co., Inc., 27 Park Place, New York 7, announces the new Universal Type *Hand Tachometer,* Type U, imported from Switzerland. These instruments are said to be small in size, fitting neatly into the palm of the hand. The importer states that they are non-magnetic, direct reading, well damped to cut out oscillations. Readability is said to be as close as 1 rpm per division, as the overall range is broken down into five special ranges.

Four models are available for all speeds between 30 and 48,000 rpm. Bulletin No. 750 describing these instruments in detail is available from the importer.

National Lubricating Grease Institute Appoints Carl E. Bolte General Secretary

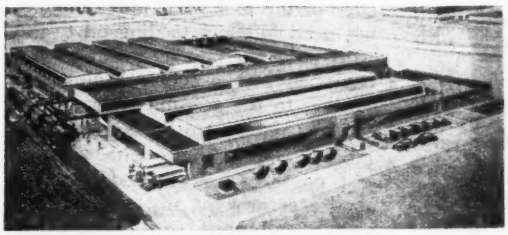
Announcement has been made of the appointment of Mr. Carl E. Bolte as Executive Secretary of the National Lubricating Grease Institute, who began his new duties July 1st.

Mr. Bolte recently returned from a month's stay in the British Isles where he was sent on an Anglo-American mission by the President of Rotary International, of which he is a director.

Mr. Bolte came to the National Lubricating Grease Institute with a distinguished record of service in business, church and civic enterprises. Most recently he has been the associate national director of the American War Dads. Before assuming these duties he had been president and general manager of the Slater Mill & Elevator Co., Slater, Missouri, during which period he also served as president of the Missouri Millers' Association and director of the Millers' National Federation. Mr. Bolte is at present chairman of the board of directors of the Missouri State Chamber of Commerce, having previously served two years as president of that body. He has been a member of the Missouri State Planning Board. For two years during the war he served as director of the Industrial Service Division, Smaller War Plants Corporation, in Washington, D. C.

Appointment of Mr. Bolte as full-time Executive Secretary marks another step forward in the thirteen year history of the National Lubricating Grease Institute. Founded in 1933 for the purpose of developing and disseminating information pertinent to the industry, the N. L. G. I. today includes among its members most of the leading grease manufacturers of the country. Its Technical Committee, in addition to developing the widely-used N. L. G. I. grease classification, has done an immense amount of research and development work, operating independently and also in cooperation with committees from other technical societies, and with governmental and military agencies.

Lincoln Engineering Company Expands Production Facilities



Inllustrated in the architect's drawing above is the plant of the Lincoln Engineering Co., St. Louis, with its new addition under construction. This addition, which is the third in ten years, adds 20% to the floor space and provides for enlarged Engineering and Production facilities. Completion by midsummer will give relief to the company's expanded demand for Lubricating Equipment and allied products.

Announcement of two new appointments is made by Dr. R. H. Patch, Vice-President in Charge of Operations, E. F. Houghton & Co.

Dr. James T. Eaton, formerly Research Assistant to the Vice-President, has been made Manager of Research, in charge of the company's laboratories and product development. Dr. Eaton, a graduate of Central College, Missouri, and who completed his graduate work at the University in 1934, has been with E. F. Houghton & Co. since 1937.

Henry H. High, formerly Superintendent of Laboratories, has been named Superintendent of the Philadelphia Oil Department, in place of D. M. Harvey, resigned. Mr. High has been associated with Houghton since 1930, following graduation from Franklin & Marshall College and special metallurgical courses at Temple University.

Sulphur and Chemical Additives

MODERN DEVELOPMENTS FOR THE

☆ OIL AND METAL INDUSTRIES

BURNS LABORATORIES, Inc.
514-520 WEST WYOMING STREET
INDIANAPOLIS 2, INDIANA

Copy of this booklet available upon request.

New, Improved Bucket Pump

Lincoln Engineering Company, St. Louis, Missouri, announces a new bucket pump known as the *Porto-Pak*. This improved high-pressure grease gun is of all steel construction and holds 30 lbs. of lubricant. The Porto-Pak features a positive automatic venting device in the pump tube assembly which operates instantly when the pump handle is raised momentarily to topmast position. This venting device relieves pressure in the hose assembly permitting lubricant to drain back into container, saving lubricant and eliminating dripping when coupler is disengaged from the grease fitting. The venting device is wear-proof and has no moving parts or springs.

Other outstanding features of the Porto-Pak are said to be:

Ease of Operation—up and down pumping action; no gears or crank.

Quickly Refilled — full open top provides maximum filler opening. Top easily removed by merely loosening two thumb-nut fasteners. Container design permits use of follower plate when pumping heavy lubricants.

Rugged Construction — container and lid are made of heavy-gauge steel.

Container has reinforced bottom.

Footstep is welded across bottom of container, providing added protection and permitting ease of operation on uneven surfaces.

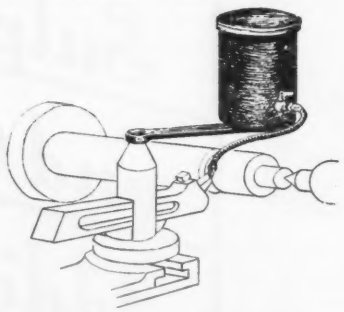
Convenient to Carry — Sturdy handle for exceptional ease in lifting and carrying. The handle is equipped with holder for coupler; keeps coupler and hose assembly off the ground and out of way when not in use.

The Lincoln Engineering Company, St. Louis 20, Missouri, will be glad to send complete information upon request.

Catalog of Cleaning and Drawing Compounds

A twenty-four page catalog of information regarding thirty-nine different cleaning and drawing compounds has just been released by Northwest Chemical Co., 9310 Roselawn, Detroit 4, Michigan. Five general classifications of Cleaners are covered namely: (1) Electrolytic, (2) Immersion, (3) Solvent, (4) Spray and (5) Water Wash compound for spray booths. The five types of drawing compounds that are described are particularly designed for (1) *Superdraw* "B" for brass and brass alloys, (2) *Superdraw* "V-113" for cold rolled steel, enameling iron, stainless steel and aluminum, (3) *Superdraw* "V-125" for steel alloys and stainless steels . . . also aluminum and brass, (4) *Superdraw* "M-99" designed for particularly heavy draws where only graphite or sulphur have been successful in the past. Emphasized is the "Lo-Hi" pH process of cleaning metal preparatory to enameling or plating. It consists of both a low pH solution and a high pH solution, in separate tanks (two baths) to provide for the thorough removal of soil regardless of the degree of alkalinity or acidity.

Coolant Reservoir



The Tru-Punch Company, Box 14, Kingsbridge Station, New York 63, announces the *Coolant Cup*—a reservoir for coolant or cutting oil which can be quickly attached to any lathe, milling machine, grinder, drill press, or other metal cutting machine. The purpose of the Coolant Cup is to hold a supply of coolant, and to permit it to be flowed or dripped to the cutting tool by means of an adjustable shut off cock, and a flexible metal hose which is quickly positioned and stays put.

The flexible metal hose is furnished in 9″ length, but is available in 12 and 15 inch lengths upon request. A special cast bracket is furnished which permits quick mounting and dismounting of the entire assembly from the tool post of a lathe. When thus used, long heavy cuts are made possible with an automatic feed. Since the cutting oil follows the tool there is no danger of dulling or burning the cutting edge of the tool. The operator does not need to stand feeding oil to the work as in the past on machines not equipped with a coolant pump, according to the manufacturer.

The Coolant Cup is available in 1 or 2 quart capacity with a heavy cast cover. It is claimed to be a good accessory for any machine not already equipped with a coolant pump. The initial cost is small and is quickly made up by the economy that is made possible through taking heavier cuts without dulling the tool, and by the better finished surfaces that are obtained. The operator of the machine is also freed to perform other duties.

New Tapping Lubricant

Efficient tapping at a reasonable cost always has been a problem in machine shop practice. To quote a prominent Ohio firm, "Tapping always has been a headache . . . and an expensive one." Now comes the announcement of a new member of the series of "Products of Matchless Merit," known as *Micronoil Tap-Eze*.

It is claimed that this lubricant gives a smoother cut, at a lower temperature, with greater speed and with a marked lowering of costs thru longer tool life. Tap breakage practically is eliminated. Interested readers should write for test sample to Protective Coatings, Inc., Detroit 27, Michigan.

Grinding Process

A new process for the wet grinding of ferrous and non-ferrous metals and alloys has been announced by Quaker Chemical Products Corp. of Conshohocken, Penn. Correct application of the Quaker Microgrind Process is said to make possible elimination of grinding cracks, prevention of burns and distortion caused by generation of heat during grinding and increased production of ground work.

The Microgrind Process includes the use of specially developed Microgrind fluids which are entirely free from difficulties due to rancidity or odor when used with extremely hard water or when used for the grinding of cast iron. The Microgrind fluid is claimed to have a highly detergent action on abrasive wheels which causes them to be kept open and free cutting. Surface finish of the work piece then becomes a true reflection of the particle size of abrasive in the grinding wheel.

Lubricant Pump

The McIntyre Co., 15 Riverdale Avenue, Newton 58, Mass., announces their Series 1200 Pump, designed for the pressure lubrication of bearings of machine tools, Diesel engines, turbines, generators and other high-speed and heavy duty machinery. The pump is a light weight (10 oz.) gear type, with aluminum body and nitrided nitralloy spur gears and shafts. It is designed for direct motor application but can be furnished for flange mounting, belt, spline and other drives.

Three standard models displace from .08 to 1.0 gpm at speeds ranging from 1140 to 5000 rpm against pressures up to 500 psi. Power requirements vary between 1/100 and 1/16 hp.

Protective Oil

Announcement of a new product for the prevention of rust on ferrous surface between operations and while parts are in storage is made by Oakite Products, Inc.

Known as Oakite Special Protective Oil, it has already found wide use in many plants where temporary or semi-permanent surface protection from rust is desired for parts or work, following such operations as grinding, machining, pickling, tumbling, sand blasting, brazing, etc.

Oakite Special Protective Oil is said to impart a thin, transparent, rust-preventive coating which does not interfere with accurate gauging or stain or discolor ferrous surfaces. Parts to be rust-proofed either may be immersed dry, or, because of the water displacing properties of Oakite Special Protective Oil, may be immersed immediately after cleaning and rinsing, while parts are wet, thereby eliminating the necessity for drying surfaces by a special hot rinse, air, sawdust or other methods generally used for drying prior to applying rust-preventive.

In addition, finger prints or similar marks resulting from inspection or handling of machined work in process can be readily removed by adding 5% water to the Oakite Special Protective Oil.

A new, free, 16-page booklet describing the many industrial applications of this product is available upon request to Oakite Products, Inc., 57 Thames Street, New York 6, N. Y.

Cutting Oil Bases

Three new cutting oil bases for use in the metal-working trades, including a unique, extreme pressure cutting oil base known as Nopco 1009-C, in which sulphur and chlorine are combined in non-corrosive form, have just been developed in the research laboratories of the National Oil Products Co., chemical manufacturers, of Harrison, N. J., according to Edwin J. Barth, Petroleum Technologist of the Specialty Sales Division.

Recommended for steel, brass and copper cutting operations in which frictional loads are extremely high, Nopco 1009-C is a specially prepared fatty oil base containing a high content of equal parts of sulphur and chlorine, Mr. Barth revealed. Absolutely odorless and free from tarry matter, it blends in all proportions with any diluent petroleum oil, down to required viscosity, sulphur and chlorine specifications.

"Blends of this base are non-rusting and non-corrosive on ferrous metals," Mr. Barth pointed out.

A powerful, sulphurized cutting oil base, known as Nopco 1009-A, and a soluble cutting oil base, described as Nopco 2009-A, also have been developed, Mr. Barth said. The former contains 15 per cent sulphur in both chemical combination and active form, and is recommended for straight cutting operations on ferrous metal.

"It is too powerful to be used in present form in most cutting operations, and is used commercially by dilution or blending with low viscosity mineral oil in which this base is completely soluble," Mr. Barth explained.

"Such blends may contain anywhere from 1 per cent to 10 per cent of total sulphur, depending on the type of cutting to be done."

Finished parts show a much greater amount of clear, smooth finish and non-rusting surfaces than objects machined with the average commercial oils found on the market today, because of the specific fatty oil used in the 15 per cent base, Mr. Barth said.

The base oil is absolutely free to tarry matter and pitches, due to the carefully controlled conditions used in manufacturing the product, he added. This is evidenced by the clear, transparent color. This quality also results in the product being free of acid by-products which are the cause of later rusting of the finished work pieces.

Blended oils of various sulphur contents are adapted for operations all the way from high-speed, light load, to extremely heavy cutting operations, such as used in making locomotive parts and in boring of modern gun barrels.

The Lincoln Engineering Company and many friends were saddened by the passing of Jack L. Carmitcheal on May 31st. Mr. Carmitcheal occupied the position of Vice President and had been active in the company for many years. His passing is regretted by his many friends throughout the country.

Philadelphia Chapter Signs Up Sustaining Member For South Africa

Harold H. Jones & Company, Ltd., with main offices in Capetown and Johannesburg, South Africa, has been noted for many "firsts" in South Africa. Mr. Harold H. Jones, Managing Director, and principal stockholder, on a recent visit to Mr. Geen, of our Philadelphia Chapter, was quick to appreciate the advantages of belonging to the A.S.L.E. and became the first sustaining member from South Africa. He expects the exchange of data through the Society and the Journal will be most helpful in his new activities.

Mr. Jones has spent the past nine months in the United States completing his post-war program. Established in 1919, this company represents a well-known group of American firms throughout South Africa; typical amongst them are: Borg-Warner International Corporation, Firestone Tire & Rubber, Super Mold Corp, Brunner Compressers—to which has now been added exclusive distributorship for Sun Oil Company's products in South Africa.

For many years Mr. Jones represented Overseas Motor Corporation (Division of General Motors) New York, until that firm opened their own branch in South Africa, when he was immediately appointed by Borg-Warner. In short, his activities have been tied in with the field of lubrication and the distribution of American machinery of various types, since he first landed in South Alfrica in 1910.

Mr. Jones extends an invitation to visiting members of the A.S.L.E. who may be doing business in South Africa, to call upon him or his staff at Capetown, Johannesburg, or any of the compar 's distributing offices established in the inland and coastal towns of South Africa.

Mr. T. W. Allison, now under jurisdiction of the Foreign Sales Department, Sun Oil Company, will shortly make his headquarters in Johannesburg for Harold H. Jones & Company, Ltd., and will be the company member of A.S.L.E. in that area. This modern city of over 500,000 population is approximately 1000 miles inland from Capetown, where Mr. Jones makes his headquarters. Should visiting members fail to call on this active firm, they will be overlooking an opportunity to learn something of a very interesting country.

Plastic Bearings Aid In Search For Greater Power

Unique experiments with transparent plastic models of machine bearings are revealing "inside information" that may result in more powerful motors for the nation's factories, research engineers of the Westinghouse Electric Corporation disclosed recently.

Plastic models are enabling scientists to look inside a moving bearing and see what is happening to the lubricating oil, according to John Boyd, Westinghouse research engineer who developed the novel technique.

One peek at these plastic models in operation often is better than weeks of mathematical calculations. Guess-work is eliminated. Now engineers can see what is happening and can design bearings which will handle a heavier load and help make possible more powerful motors without any increase in size or weight.

The procedure is simple. Oil, colored with a red pigment, is fed into the bearing model and the effectiveness of the lubrication is quickly apparent. Engineers know at once whether the seals work properly, whether the oil passages are enabling a proper flow of the lubricant, and whether the relief points are located correctly.

Blocks of Lucite, a transparent plastic, are machined to close tolerances just like metal to form the models of bearings and journals. During the actual operating tests, the rotating element of the finished model is operated by a hand crank for slow speeds and is motor driven
ı speeds.

Necrology

Dr. A. W. Burwell

Born in Rock Island, Illinois, in 1867, and educated in Cleveland, Dr. Burwell received his Ph.D. in Strassburg in 1892, where he studied under Fittig, Kohlrausch, Rose, Wolff and other famous masters. During his last year in Germany, he was honored by Professor Fittig by being placed in charge of his laboratory. Upon his return to America, he started work on general petroleum refinery problems with the Standard Oil Company, Cleveland, January, 1893. His career has been an active one ever since. While largely concerned with petroleum, he also worked in other fields such as petroleum pitch, electrode manufacture, electrolytic oxidation of organic compounds, minerals separations, etc. He was a registered pharmacist at the age of twenty; he also taught chemistry and at one time served as consulting chemist for a nitro glycerine factory. During an extended "vacation" in Montana, he homesteaded a piece of land and had many interesting experiences in the wilds.

Dr. Burwell pioneered in the oxidation of petroleum on which work he has written numerous articles and received many patents.

The Schoellkopf Medal was awarded to him in 1941 by the Western New York section of the American Chemical Society in recognition of his fundamental work in the oxidation of petroleum, his development of commercial processes for producing materials useful as lubricants and rust preventives, his studies in the theory of lubrication and his successful career of fifty years as a chemist.

Due to ill health, Dr. Burwell has not been active in the management of the Alox Corporation for the last several years.

C. A. Beach

Mr. Beach was born in Princeville, Illinois, January 6, 1891. He entered the oil business some twenty-five years ago with Empire Refineries, Inc. (Cities Service Oil Company) where he stayed for about fifteen years. He was then with the Great Lakes Coal and Coke Company at Kansas City, Missouri, for three years, and served as president for two years at the Ideal Refining Corporation, St. Louis.

He joined the staff of the Industrial Sales Department of the National Refining Company in 1942 and served as Lubricating Engineer until his death on May 9th of this year.

A day or so previous to this, Mr. Beach was called to Quincy on a lubrication problem, and on the way suffered a heart attack which resulted in his death a few days later at Blessing Hospital in Quincy.

A.S.L.E. SECTION ACTIVITIES

Pittsburgh Section

Pittsburgh Chapter held their regular monthly meeting on April 26 at Webster Hall Hotel. Dinner was served to forty-six and several more dropped in later for the business session.

Chairman Svenson introduced Dr. E. M. Kipp, who had just been elected National President of the American Society of Lubrication Engineers and who outlined the aims of our Society and gave us a brief discussion on what we hope to accomplish during 1946 and 1947.

The members then introduced guests that they had for the evening.

Mr. G. L. Sumner reported on the Chicago Convention and read us the minutes of the directors' meeting that took place in Chicago after the regular convention. It was moved and passed that the Chairman of the Pittsburgh Section appoint a counselor in line with the recommendations of the National Office. It was moved and passed that the Pittsburgh Section invite the National Convention to Pittsburgh in 1947.

The secretary's and treasurer's reports were read and approved.

The meeting was turned over to Dr. Mahncke, chairman of the program committee, who introduced Mr. Sam Fink of the Alemite Corporation, who discussed the army movies shown covering all phases of lubrication as they applied to mobile equipment in the army. After showing the movies, considerable discussion occurred from the floor.

The May meeting was held at the Windsor Hotel in Wheeling, West Virginia. Dinner was served to sixty-eight and several more dropped in later for the business session.

As there were many present who had never attended a meeting of our society, Chairman E. V. Svenson introduced Mr. C. E. Pritchard, past national president, and Dr. E. M. Kipp, our present national president, both of whom gave brief talks that were full of interest.

During the business session it was decided to hold a golf match some time during the summer patterned after the one held last summer and the entertainment committee to handle the necessary arrangements.

Dr. Mahncke then introduced Mr. R. L. Churchill of Tide Water Associated Oil Company, who gave a very interesting and informative paper on "Extreme Pressure Lubricants as Applied to Steel Mill Operations." This paper seemed to arouse more than the usual amount of discussion and a very informative discussion session developed after Mr. Churchill read his paper.

G. H. DAVIS, *Secretary.*

Cleveland-Youngstown Section

The Cleveland-Youngstown Section held its first annual golf party and dinner on Tuesday, June 25th, at the Shady Hollow Country Club some 50 miles southeast of Cleveland.

The course was beautiful, the weather perfect, and the dinner delicious. There were golf prizes and door prizes and the affair was unanimously voted a rousing success.

The coffee speaker was Jack (Ironsides Co.) McPhee, who has been a football official for many years. His talk regarding the mechanics of football officiating was most interesting and well received. He also showed films of important football games as well as the 1945 World Series.

There were 50 persons present for the dinner, approximately half of whom played golf.

Baltimore-Washington Section Holds Preliminary Meeting

Under the able guidance of Mr. Paul F. Chappell, a preliminary organization meeting was held by a group of members interested in forming a section in Baltimore.

The result of the meeting was the decision that a petition will be sent to the National Association for the formation of a Baltimore Section. Early in the fall the organizational meeting will be held and the election of Officers will take place. At that time the desirability of forming a combined Baltimore-Washington Section, or of forming two Sections, will be considered. In any event, it is probable that joint meetings will be held with attendance by members both from Baltimore and Washington.

Buffalo Section Organizes

On Thursday evening, June 27, 1946, the organization meeting of the Buffalo Section of the A.S.L.E. was held at the Markeef Hotel. Fifty-four members, guests, and National Officers were present. Particularly gratifying were the large number of users in attendance. Arrangements for the meeting were made by Mr. James Farry, the Alemite Company, Buffalo, New York. Those present enjoyed an excellent chicken dinner, and music and singing were enjoyed during the meal.

Short talks on the purpose and objective of the A.S.L.E. were given by Mr. Charles Pritchard, Mr. George Sumner and Mr. W. T. Everitt, Directors of A.S.L.E.; Dr. George Von Fuchs of Wood River, Illinois, and Dr. Parche of Niagara Falls, New York, Mr. James Courtright of Toronto, Canada and Mr. Henry van Olphen of Amsterdam, Holland gave short talks.

The formal part of the meeting followed. The talks were excellent and well received. Real enthusiasm was expressed and a temporary organization was set up to arrange for a fall meeting, at which time a permanent organization will be established.

Temporary Officers are:

Chairman—
Walter G. Peuchen
Hershey Corporation
Buffalo, New York

Co-Chairman—
James M. Courtright
Shell Oil Co. of Canada
Toronto, Ontario

Secy-Treas.—
James Farry
Alemite Company
Buffalo, New York

Program—
W. T. Everitt
Eastman Kodak Company
Rochester, New York

The next meeting will be held in September, probably in Niagara Falls, Canada.

Dr. Kipp, National President of the Society, also was present at the meeting and briefly spoke of present and future plans of the Society.

Chicago Section Holds Golf Tournament

Mr. L. R. Kerns and his very efficient Tournament Committee arranged a splendid outing followed by golf and dinner at the Navajo Fields Country Club on July 16, 1946. About fifty were in attendance, most of whom participated in golf.

In the evening a fine dinner was served and the lucky winners were awarded their prizes.

The Chicago Section was sorry to see its Secretary-Treasurer leave the "Windy City," but we know Bob Sharpe will be equally active in the Society in New York.

Robert Q. Sharpe, Assistant Technical Manager of the Industrial Department of Socony-Vacuum Oil Company, Chicago Branch, left July 15th to become Staff Engineer for air-compression and vacuum-pump Lubrication in the Technical Deparment of the New York office of the company. He has been with Socony-Vacuum for four years, coming there from managing the Chicago office of the Hoffman Company. Mr. Sharpe is a graduate of the University of Kansas.

Harry Krummell has succeeded Mr. Sharpe as Secretary-Treasurer of the Chicago Section. Active section plans are being made for the coming season with an interesting series of meetings. One type of meeting will be of the "Information Quiz" form so successfully carried through at Milwaukee last year.

New York Section

The basic theme underlying the various talks presented at our Second Meeting of the year was the Importance of Synthetic Lubricants and their present status in the Field of Lubrication. This Meeting was held in the Shelton Hotel, New York City. The 150 members and guests who attended this meeting represented prominent engineers from the Bearing Industry; Automotive Field; Oil, Chemical and Metal-Working Industry.

A very fine paper was presented by Mr. T. A. Kauppi, Dow-Corning Co., Midland, Mich., on "Silicones." In his talk, Mr. Kauppi traced the history and development of Silicones; their entrance into the Field of Lubrication; the various types of Silicone Lubricants now available; the engineering work behind their evaluation; and their present application. Each point of interest was clearly illustrated by means of lantern slides.

The second paper of the evening was presented by Mr. J. M. Russ, Jr., Special Products Division, Carbon and Carbide Co., New York City. His paper entitled "New Synthetic Lubricants" on this very timely subject created a great deal of interest.

As in the case of the "Silicones" described by Mr. Kauppi, the new synthetic automotive and industrial lubricants described by Mr. Russ are also recent developments and newcomers in the field of lubrication. Slides depicting the various physical characteristics of these lubricants were also shown.

Another interesting phase in the development of synthetic lubricants was presented by Mr. Edward G. Egan, Celanese Chemical Corp., New York City, in his paper "A Synthetic Lubricant for Hydraulic Fluid."

It was learned that the presence of a serious fire hazard, when petroleum oils were used as hydraulic fluids in die casting machines, precipitated the development of "Lindol." This product is a non-flammable organic phosphate compound with hydraulic fluid characteristics. The chemistry behind the development of this product and its success were clearly described and illustrated. Other important uses for this chemical in lubricants were also described.

The general concensus of opinion as deduced from the remarks of such outstanding petroleum engineers as Mr. C. M. Larson, Sinclair Refining Co.; Mr. M. L. Langworthy, Texas Co.; Mr. Bruce Boehm, Stanco Distributors, Inc.; Mr. L. C. Beard, Jr., Socony-Vacuum Oil Co., was that there is apparently a definite place for synthetic lubricants in industry. Furthermore, as synthetic lubricants are still in the early stages of development, they will require close observation and study before becoming more firmly established.

The Ball Bearing Manufacturer's point of view on Synthetic Lubricants was presented in an excellent paper by Mr. C. R. Gillette, New Departure Division of General Motors Corporation. In his paper, Mr. Gillette discussed the various efforts which have been made to apply

A.S.L.E. Section Officers

CHICAGO:	Chair., Mr. W. F. Leonard, 4541 Sheridan Rd., Chicago, Ill. V. Chair., Mr. D. N. Evans, Inland Steel Co., E. Chicago, Ind. Secy.-Treas., Mr. R. Q. Sharpe, Socony-Vacuum Oil Co., 59 E. Van Buren St., Chicago, Ill.
CLEVELAND-YOUNGSTOWN:	Chair., Mr. C. A. Bierlein, G. M. C., Cleveland Diesel Engine Div., 2160 W. 106th St., Cleveland 11, Ohio. V. Chair., Mr. R. J. Hagan, Republic Steel Co., Youngstown 1, Ohio. Secy.-Treas., Mr. L. W. Fitch, Dingle-Clark Co., 1248 Engineers Bldg., Cleveland 14, Ohio.
MILWAUKEE:	Chair., Mr. Oscar Frohman, Ampco Metal, Inc., 4478 N. Cramer St., Milwaukee 11, Wisconsin. V. Chair., Mr. G. Radosevitch, Harnischfeger Corp., 1622 S. 13th St., Milwaukee 4, Wisc. Secy., Mr. R. Ley, Shell Oil Co., 3240 S. Burrell St., Milwaukee 7, Wisc. Treas., Mr. C. Beck, Globe Steel Tubes, 2958 N. 21st St., Milwaukee, Wisc.
NEW YORK:	Chair., Mr. D. D. Fuller, Dept. of Mech. Eng., Columbia Univ., New York 27, N. Y. V. Chair., Mr. Henry Lee Norris, 600 W. 116th St., New York 27, N. Y. Secy.-Treas., Mr. A. J. Zino, 27 Shoreview Rd., Manhasset, N. Y.
PHILADELPHIA:	Chair., Dr. Edgar S. Ross, Sun Oil Co., 1608 Walnut St., Philadelphia 3, Pa. V. Chair., Mr. William P. Kuebler, Westinghouse Electric Corp., Philadelphia, Pa. Secy.-Treas., Mr. J. H. Richards, Apex Alkali Prod. Co., Main & Rector Sts., Philadelphia 27, Pa.
PITTSBURGH:	Chair., Mr. E. B. Svenson, Sr., Aluminum Co. of America, New Kensington, Pa. V. Chair., Mr. Mark A. Stillwagon, Carnegie-Illinois Steel Corp., Homestead, Pa. Secy.-Treas., Mr. George H. Davis, Shell Oil Co., 1102 Grant Bldg., Pittsburgh, Pa.

both the fluid as well as the solid or grease type of synthetic lubricants to ball bearings. Their advantages, as well as their present weaknesses, were pointed out. The fundamental requirements, which must be met by ball bearing lubricants, were also stressed. Three lubricants are required for the lubrication of bearings: (1) An improved product for the majority of applications which operate between –40F and 175-200F, (2) a product for temperatures below –40F, and (3) a product for applications over 200F. Mr. Gillette was particularly pleased with the progress being made in the development of synthetic lubricants and their future importance.

Mr. F. L. Wright, Norma-Hoffman Bearing Corp.; Mr. F. Leister, the Fafnir Bearing Co., and Mr. E. Specht, Hyatt Bearing Division of General Motors Corp., concurred with Mr. C. R. Gillette's remarks.

Our third and final Spring Meeting of the year 1946 was held in the Shelton Hotel, New York City, at 7:30 P.M., and was attended by approximately 150 members and guests. The fore part of our meeting was directed by Mr. C. M. Larson, Chairman of New York Section Nominating Committee. Proposed Section By-Laws were adopted by unanimous vote. The men who directed the Spring Activities of the Section on a Pro-Tem Basis, were officially elected for the positions indicated for the year 1946-47.

The committee chairmen elected for the year 1946-1947 were:

Mr. A. F. Brewer, *Chairman—Program Committee*
The Texas Company
New York, N. Y.

Mr. J. L. King, *Chairman—Publicity Committee*
Assistant Editor—"Power" Magazine
McGraw-Hill Publishing Co.
New York, N. Y.

Mr. C. M. Larson praised Chairman Fuller and the other officers for the splendid job which had been done in organizing the New York Section and getting it off to a flying start. Following this, the meeting was officially turned over to Chairman Fuller.

The first speaker of the evening, Dr. C. F. Prutton, Consulting Engineer for the Lubri-Zol Corporation and Head, Chemistry and Chemical Engineering Department, Case School of Applied Science, Cleveland, Ohio, was introduced by his former student, A. J. Zino, Jr. The reason for this introduction was to acquaint the Section with the outstanding development and research work which this famous scientist and chemist has done in the field of lubrication. Dr. Prutton's paper "Mechanism of Action of Sulphur-Chlorine Gear Lubricants" was one of the finest and most educational papers of its type delivered in our Section.

This entire paper was delivered in the form of slides. The Hypoid Lubricant Development was traced from 1859-1946. Pictures of the various types of automotive gears were shown and the different test methods depicted. The four general types of additives which are used in our Modern Hypoid Lubricants were described. They consisted of lead soap, sulphur and chlorine compounds blended in the finished product; secondly, organic sulphur-phosphorus compounds blended in the finished product; third, organic chlorine, sulphur compounds in the form of concentrates; and fourth, organic sulphur, chlorine phosphorus compounds in the form of concentrates.

The ability of gear lubricants, containing each specific type of additive, to resist metal-to-metal contact or scoring, were beautifully illustrated.

Test methods designed to evaluate both sulphur and chlorine compounds were described. The action of sulphur and chlorine in Shock Tests in the form of elemental sulphur, benzyl disulfide, chlorinated paraffin, etc., was presented in chart form. Of especial interest to all present were the new additive evaluation tests. Studies were presented on the Reactivity and Decomposition of both Sulphur and Chlorine Additives in the presence of iron at 205 C.

An excellent paper on the "Application of Additives in Lubricating Oils" was presented by Mr. J. W. Ramsay, Socony-Vacuum Oil Co. Basic reason for treating lubricants is to overcome the various problems created by changes in design and application. Problems such as rust, corrosion, wear, varnish formation, etc., were described.

The following additives and their applications in the automotive, aviation, and industrial fields were depicted:

1. Anti-oxidants
2. Detergents
3. Rust Inhibitors
4. Extreme Pressure Agents
5. Pour Point Depressants
6. Viscosity Index Improvers

Future in treated or processed oils is unlimited.

The third principal speaker of the evening, Mr. W. F. Aug, Mack Manufacturing Co., presented the "User Reaction to Additive Oils." Mr. Aug presented the Essential Functions of Additive Oils:

1. Prevent Corrosion and minimize fatigue failure
2. Keep rubbing surfaces "wet"
3. Remove heat
4. Minimize surface destruction
5. Possesses natural or "fortified" stability
6. Must not evolve toxic or odorous vapors
7. Possesses cleansing ability
8. Compatibility

Other factors essential to mineral oils are: adequate viscosity at operating temperatures; good viscosity index; low pour point; low channel test; and desirable specific heat.

Problems due to additives also were discussed. The use of additives in oils raised several questions which were covered by subsequent speakers.

Mr. A. L. Beall, Wright Aeronautical Corp., spoke on the oil factors of interest to the Aviation Engineer, i.e., minimizing wear, preventing corrosion, and promoting engine cleanliness. The use of additives in aviation oils are of real interest to the engine builder.

Dr. Campbell, Bell Laboratories, spoke of the various lubrication problems found in the operation of instruments and the possible application of additives in instrument oils.

Mr. G. Kaufman, The Texas Co., discussed the use of additives in greases and their fundamental purpose.

The Meeting officially closed at 10:30 P. M.

ANTHONY J. ZINO, JR.,
Secretary-Treasurer.

N.L.G.I. Announces Convention

The annual Convention of the National Lubricating Grease Institute has been announced for September 30th, October 1st and 2nd, 1946. This will be held at the Edgewater Beach Hotel in Chicago.

A very interesting and complete program has been planned and a large attendance is expected.

President Carl W. W. Georgi will open the first session, which is scheduled for 10 o'clock Monday, September 30th. Information concerning the Convention may be obtained from the Secretary of the Institute, Carl E. Bolte, Land Bank Building, Kansas City 6, Missouri.

APPLICANTS FOR MEMBERSHIP

The following applications for membership have been received during the period May 1, 1946 to July 31, 1946.*

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Carbide & Carbon Chemical Co.
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Harold H. Jones & Co., Ltd.
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Panelyte Div. St. Regis Paper Co.
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American Oil Company
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Membership in the Society is in several grades as defined below. Assignment to grade is made by the Admissions Committee or Board of Directors on the basis of information submitted or supplied by references.

MEMBERS

Members shall be: (1) persons not less than twenty-four years in age who are engaged in research and instruction at technical schools, universities and various publicly and privately supported institutions in the field of lubrication; or (2) persons not less than twenty-four years in age who have occupied recognized positions as Lubrication Engineers for a period of three or more (not necessarily consecutive) years prior to date of admission, involving the responsibility for or supervision of the development, selection, field use and application of lubricants as differentiated from other activities; or (3) persons not less than twenty-four years in age who are indirectly concerned with the field of lubrication, but possessing other qualifications of experience, knowledge and accomplishment, have manifested a particular interest in the purposes and welfare of the Society, to the extent that their membership would be a valuable contribution to the successful functioning of its activities.

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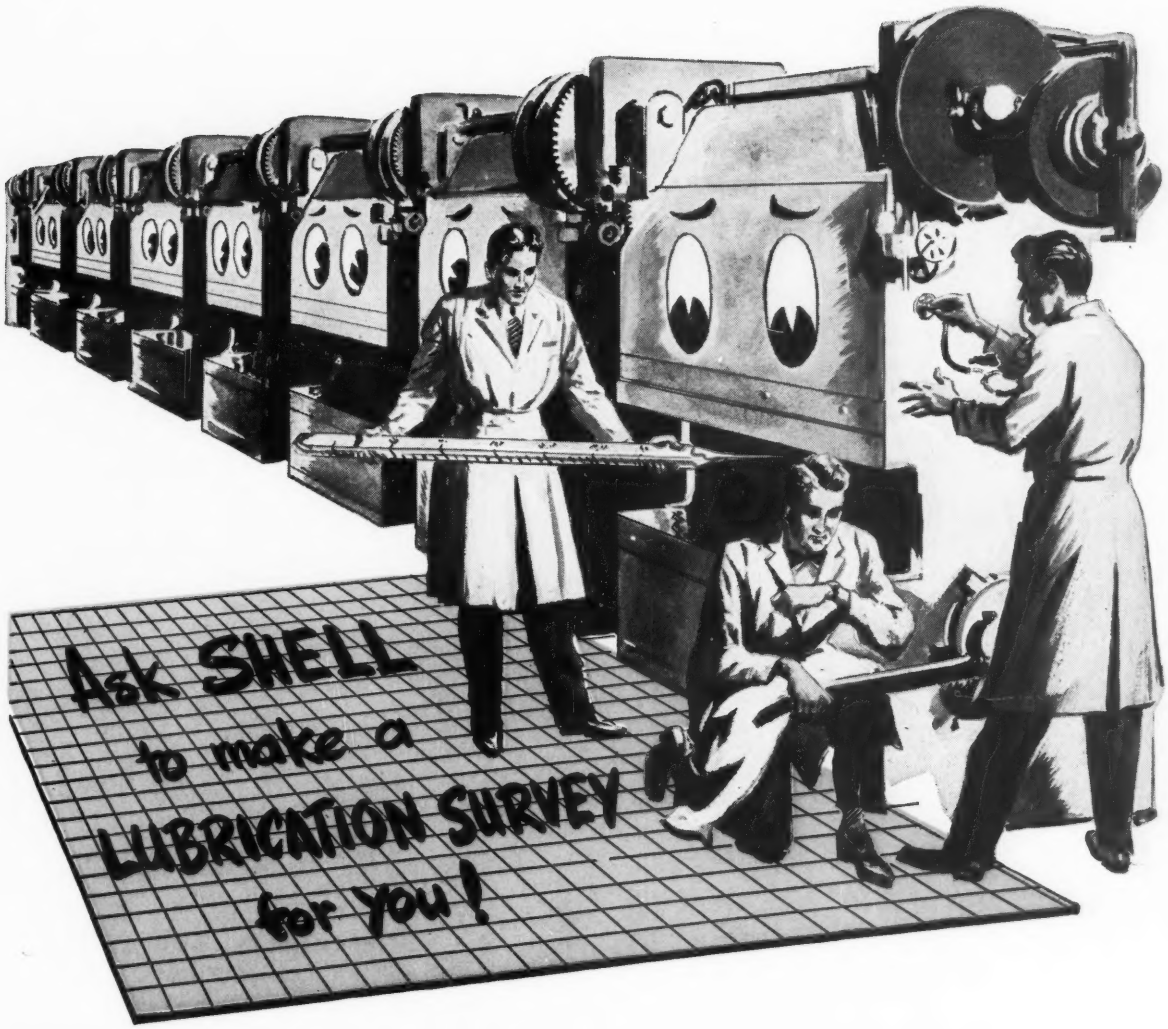

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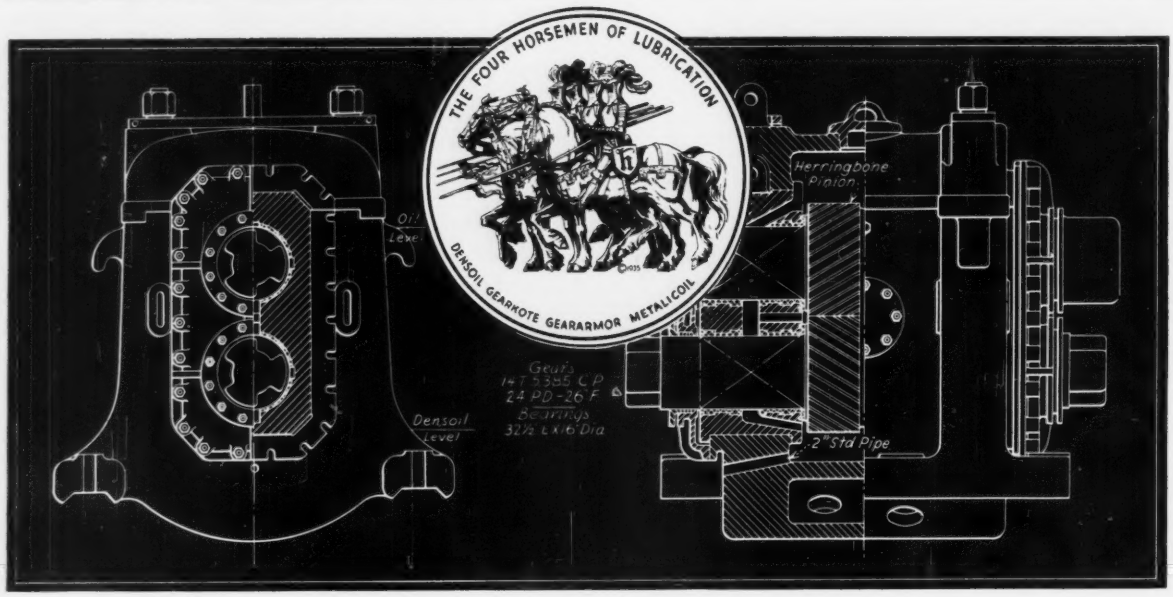

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